March 1961

75¢

SEMICONDUCTOR PRODUCTS

1961 IRE INTERNATIONAL CONVENTION – TECHNICAL PROGRAM

	WALDORF-ASTORIA HOTEL						NEW YORK COLISEUM		
	Starlight Roof	Astor Gallery	Jade Room	Sert Room	Empire Room	Grand Ballroom	Faraday Hall	Marconi Hall	Morse Hall
RCH 20	SESSION 1 Discrete and Adaptive Control Systems	SESSION 2 Reactor Instrumentation	SESSION 3 Engineering Writing and Speech	SESSION 4 Radio Frequency Interference	SESSION 5 Engineering Management		SESSION 6 Product Engineering and Production	SESSION 7 Advances in Navigation and Flight Safety Systems	SESSION 8 Electron Devices
MARCH 21 –12:30 p.m.	SESSION 9 Control Theory and Practice	SESSION 10 Nuclear Instrumentation	SESSION 11 Broadcasting	SESSION 12 Electroacoustics		SESSION 13 • Engineering Management	SESSION 14 Medical Electronics	SESSION 15 This World and the Adjacent One	SESSION 16 Broadening Device Horizons
Y, MARCH 21 0 p.m.	SESSION 17 Coding Theory	SESSION 18 Industrial Electronics Applications	SESSION 19 Broadcasting	SESSION 20 Studies in Magnetic Recording			SESSION 21 The Changing Role of Bio-Medical Electronics in Science and Technology	SESSION 22 Implementation of Reliability Predictions	SESSION 23 Microwave Devices
DAY, MARCH 21 10:30 p.m.						SESSION 24 Panel: New Energy Sources			
NESDAY, MARCH 22 00 a.m.–12:30 p.m.	SESSION 25 Detection Theory and Signal Analysis	SESSION 26 Broadcast and Television Receivers	SESSION 27 Application of Solid State Devices as Components	SESSION 28 Space Electronics		SESSION 29 • Graduate Education in Electrical Engineering	SESSION 30 Communications Systems — Techniques	SESSION 31 Mathematical Approach to Reliability Prediction	SESSION 32 Microwave Solid State
EDNESDAY, MARCH 22 2:30–5:00 p.m.	SESSION 33 Data Recording and Storage	SESSION 34 Circuit Theory I	SESSION 35 Advances in Component Designs	SESSION 36 Telemetry			SESSION 37 Communications Systems — Basic Theory	SESSION 38 Propagation	SESSION 39 Microwave Measurements
THURSDAY, MARCH 23 10:00 a.m.–12:30 p.m.	SESSION 40 Analog and Hybrid Techniques	SESSION 41 Circuit Theory II	SESSION 42 Ultrasonics Engineering I	SESSION 43 Radar	SESSION 44 Space Communication Systems of the Future		SESSION 45 Human Factors in Electronics	SESSION 46 Antennas	SESSION 47 Advances in Instrument Calibration and Precision
THURSDAY, MARCH 23 2:30–5:00 p.m.	SESSION 48 Digital Computer Techniques	SESSION 49 Symposium on Time-Varying Networks	SESSION 50 Ultrasonics Engineering II	SESSION 51 Military Electronics			SESSION 52 Vehicular Communications	SESSION 53 Antennas	SESSION 54 Advances in Instrumentation Techniques and Systems

• Sessions 13 and 29 terminate at 12:00 Noon.

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High Speed Analog to Digital Converter

Electrically Variable Time Delay Using Drift Transistors

Complementary Resistor Transistor Logic Circuits

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WITH ANY OTHER

Philco's Improved 2N1499A MADT®

ABSOLUTE MAXIMUM RATINGS

Storage Temperature	−65 to +100°C
Collector Voltage, V_{CB}	−20 volts
✓ Collector Voltage, V_{CES}	−20 volts
✓ Collector Current, I_C	−100 ma
Total Device Dissipation at 25°C	60 mw

ELECTRICAL CHARACTERISTICS (T = 25°C)

Static Characteristics	Min.	Typ.	Max.	
Collector Cutoff Current, I_{CBO} (V_{CB} = −5v)		1	3	μa
✓ Collector Cutoff Current, I_{CBO} (V_{CB} = −5v, T = 55°C)			18	μa
✓ Collector Breakdown Voltage, BV_{CBO} (I_C = −25 μa)	20			volts
✓ Collector Breakdown Voltage, BV_{CES} (I_{CES} = −25 μa)	20			volts
DC Current Amplification Factor, h_{FE} (V_{CE} = −0.5v, I_C = −40 ma)	20	50		
✓ DC Current Amplification Factor, h_{FE} (V_{CE} = −0.3v, I_C = −10 ma)	30	70		
Base Input Voltage, V_{BE} (I_C = −10 ma, I_B = −1 ma)	0.25	0.32	0.40	volt
Collector Saturation Voltage, V_{CE} (SAT) (I_C = −10 ma, I_B = −1 ma)		0.12	0.20	volt
Collector Saturation Voltage, V_{CE} (SAT) (I_C = −10 ma, I_B = −0.5 ma)		0.15	0.25	volt
✓ Base Input Voltage, V_{BE} (I_C = −10 ma, I_B = −0.5 ma)			0.34	volt
Dynamic Characteristics				
Output Capacitance, C_{ob} (V_{CB} = −6v)		1.5	3	pf
Rise Time, t_r (V_{CC} = −5v, I_C = −10 ma, I_{B1} = −2 ma)		25	60	nsec
Minority Carrier Storage Time Constant, τ_s ($(K'_s)I_B$ = −1 ma)		100	120	pcb/ma
✓ Gain Bandwidth Product, f_T (V_{CE} = −3v, I_C = −5 ma)	100			mc

✓ Checks indicate specification improvements

Now with New, Tighter "Specs"

In high-speed switching circuits, this Philco MADT has a long record of reliable performance. It has always been manufactured to meet rigid specifications . . . not selected as a fall-out device.

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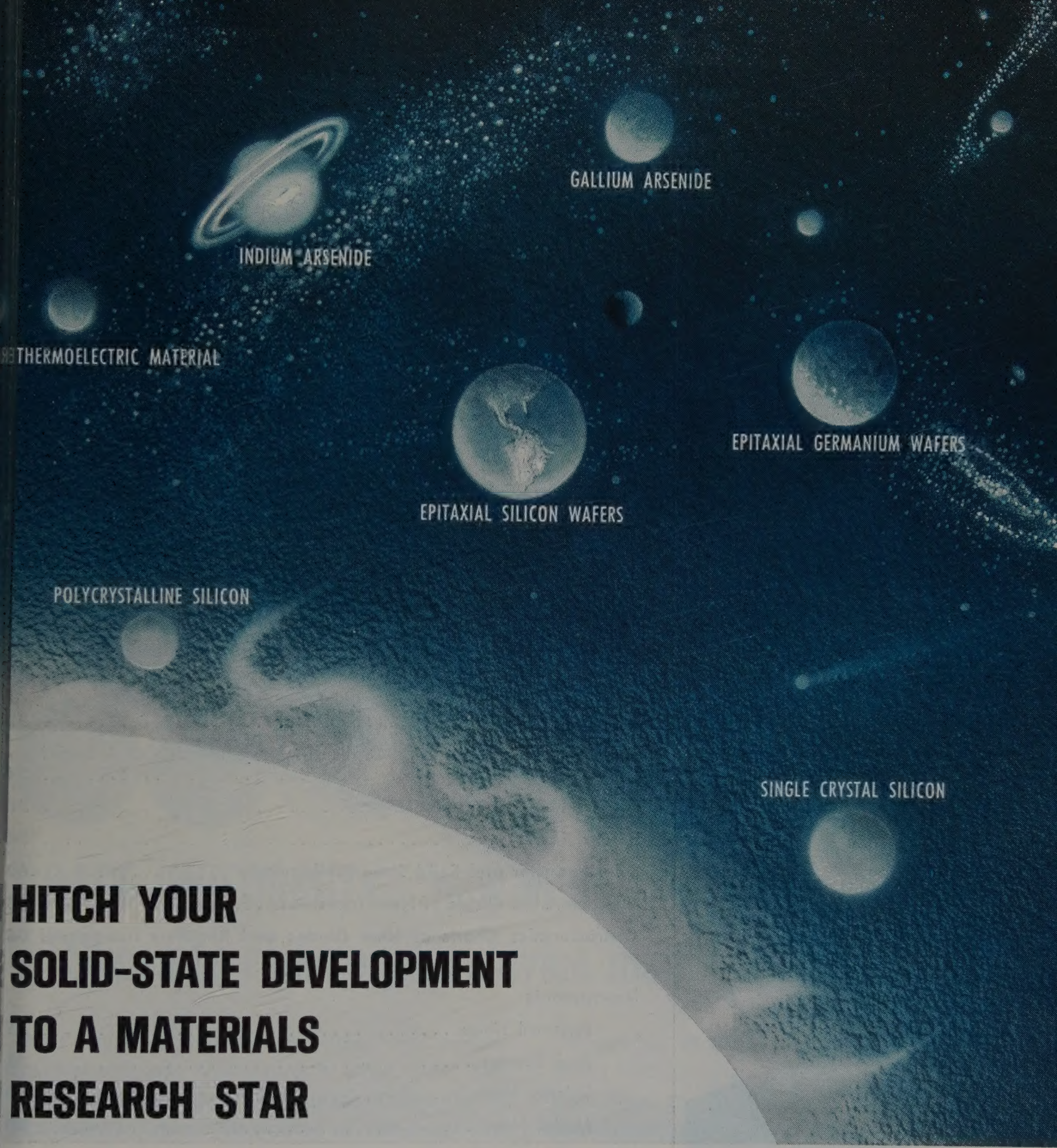

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SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

March 1961 Vol. 4 No. 3

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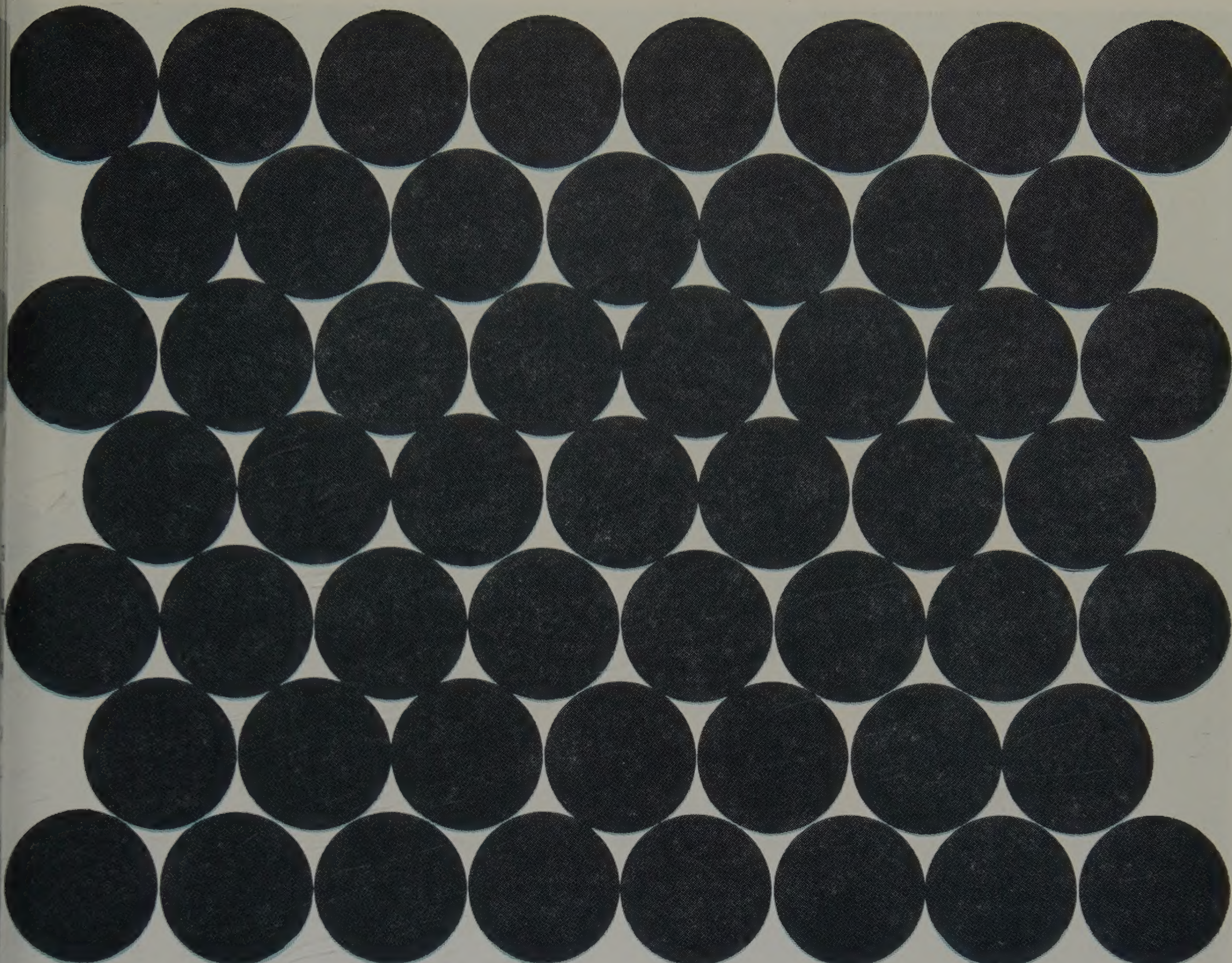
SEMICONDUCTOR PRODUCTS—BOOTH #4126—Coliseum



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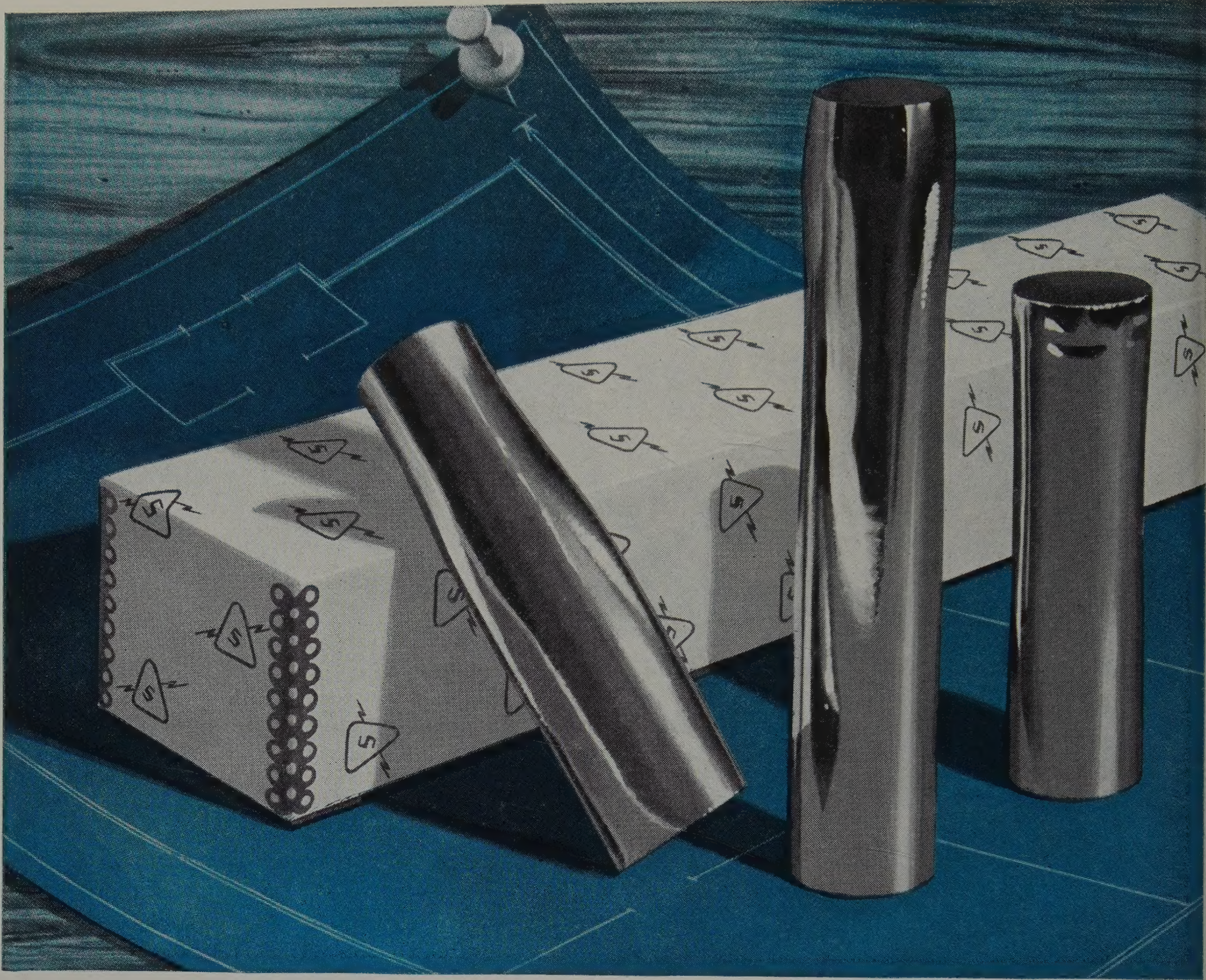

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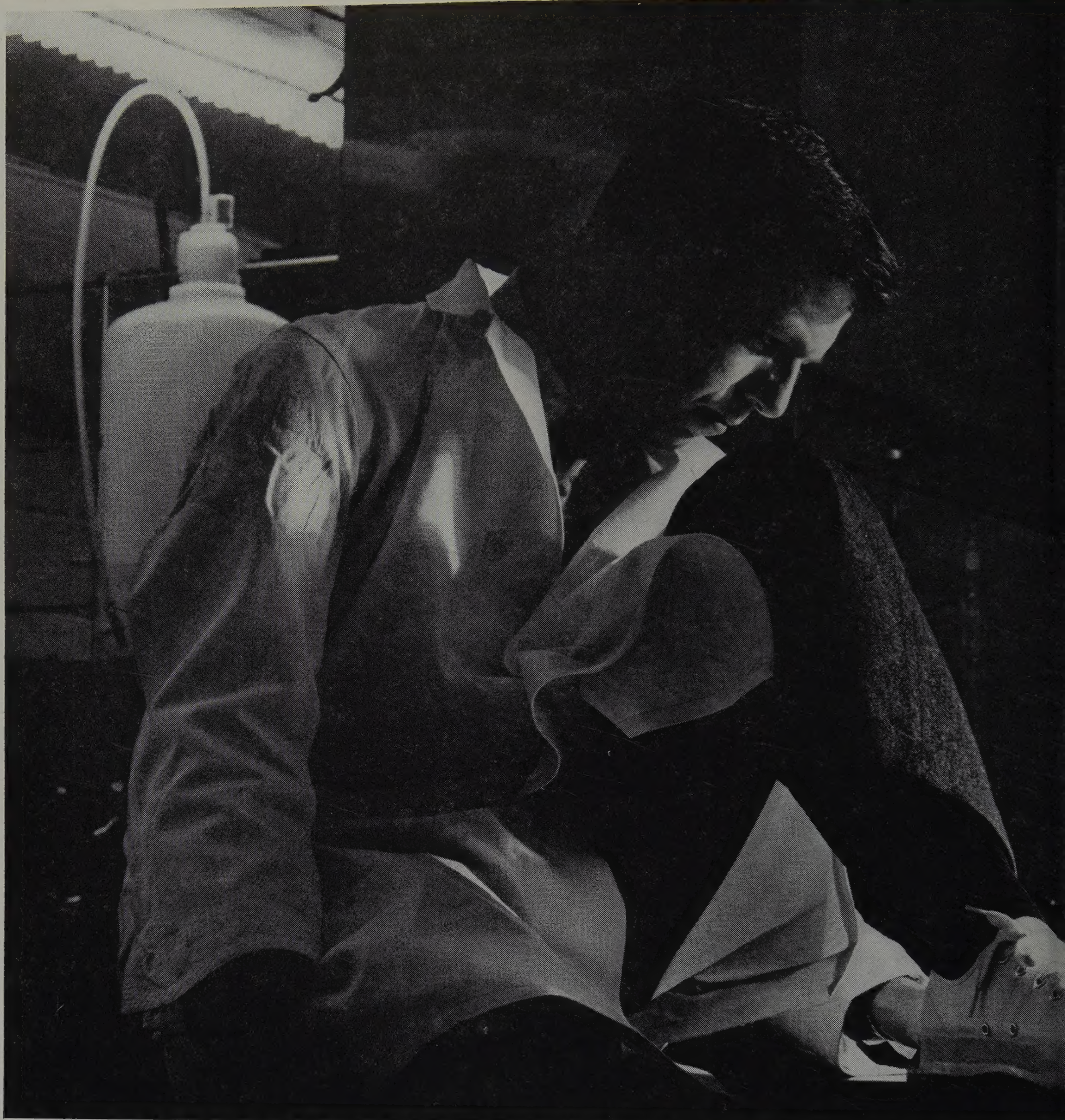

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"You'd be surprised," says Dr. John Draney of Alloys Unlimited Chemical

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quality of Arsenides,

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mentioned above *must* be dressed in special
to insure maximum product purity. Unnec-
Perhaps!

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l semiconductor compounds produced under
ngent safeguards. But more and more semi-
or engineers realize that it is dangerous to
inces with the purity of these compounds.

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they yield optimum electrical parameters).

This attention to purity is carried all the way through—right down to packaging.

Among the many product forms produced, the following Arsenides and Antimonides are available in large grain polycrystalline ingots and single crystals:

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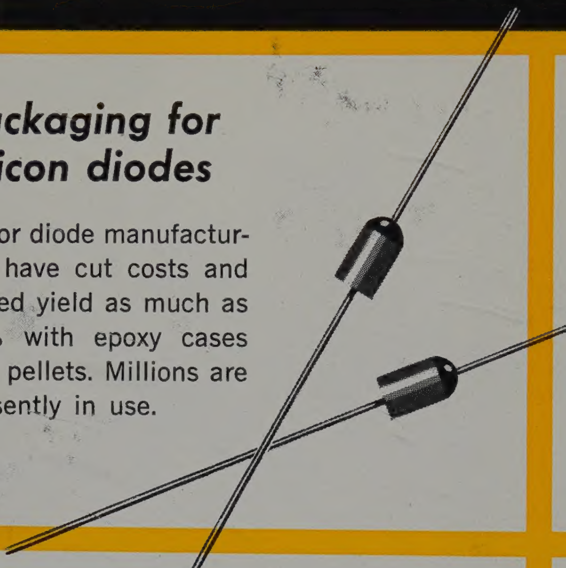


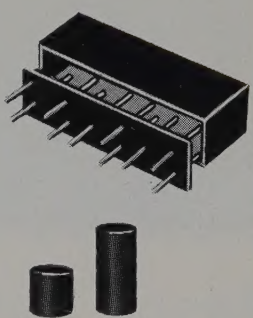
Packaging for silicon diodes

Major diode manufacturers have cut costs and raised yield as much as 47% with epoxy cases and pellets. Millions are presently in use.

Pellets for automotive diodes

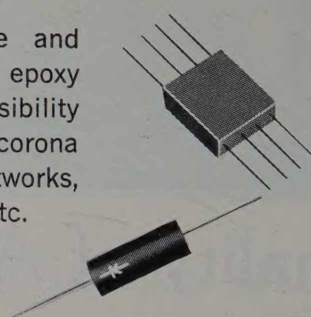
Epoxy pellet completely seals diode to withstand thermal shock from –70° to +150°C; meets auto industry specifications.

Cases for modular packaging



Standard and custom, cylindrical and rectangular shells, in 9 colors in epoxy or diallylphthalate molding compounds, for high temperature, moisture and shock resistance with high electrical characteristics.

Flame-resistant epoxy for semiconductor networks



High temperature and flame resistant epoxy shells reduce possibility of flashover or corona in rectifiers, networks, matched quads, etc.

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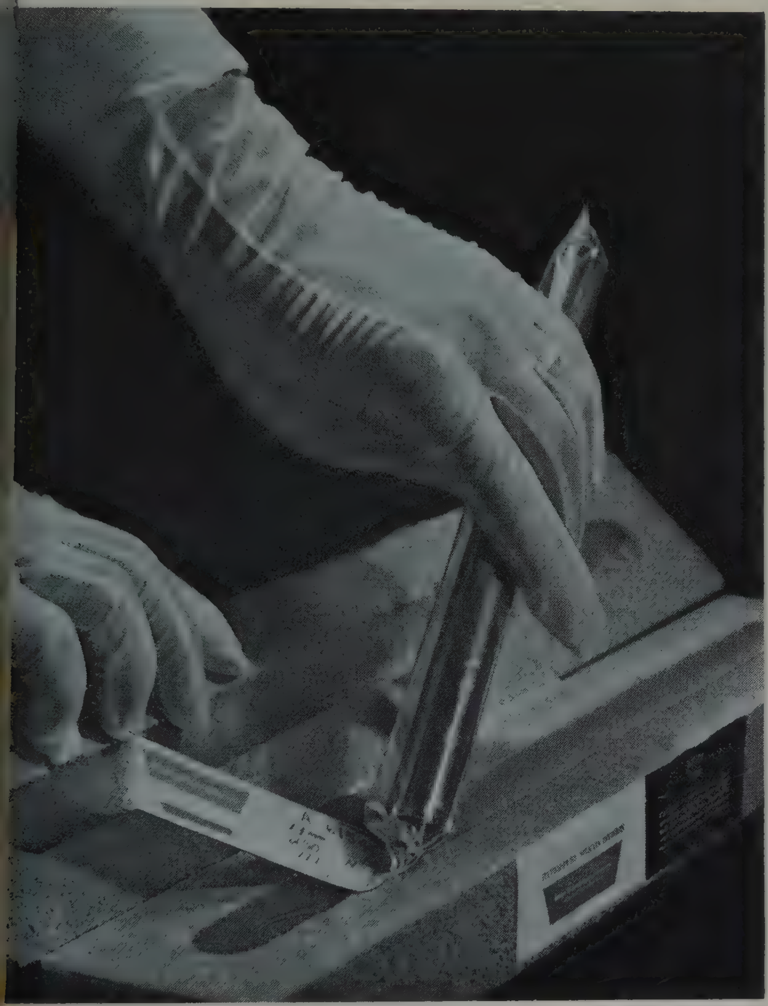
(PART 2)

The Untouchables

Single Crystal Silicon... the "Pinnacle of Purity"



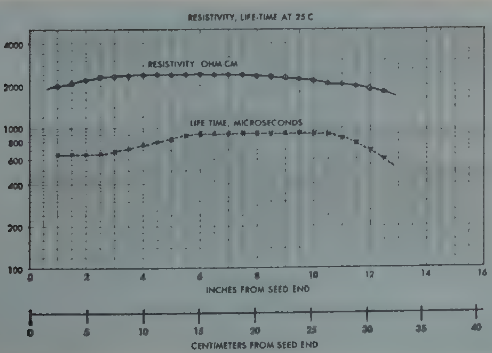
Dow Corning single crystal silicon is produced by vacuum zone refining hyper-pure polycrystalline rod. Result: The purest silicon produced! Typically, impurity content is only 0.15 part per billion of boron for crystals that are consistently above 1000-ohms centimeter resistivity. Boron content is even lower for crystals of 2000-ohms centimeter and above . . . available on a selective basis.

This highest purity P-type silicon is the result of a completely integrated processing facility that starts with the production of trichlorosilane and ends with the crystals heat-sealed in airtight polyethylene envelopes. Purity and quality control dominate every step — in producing the basic chemicals . . . in growing polycrystalline rod . . . in vacuum zone refining . . . in product evaluation and in packaging.

Purity pays off . . . in rectifiers and diodes having higher peak inverse voltage ratings — in maximum utilization because of uniform lateral and radial profiles over the entire length of the rod. With Dow Corning single crystal rod, you're assured of maximum yield and minimum waste per rod. Rod diameter variation is controlled to less than 1.4 mm (0.055 inches)— simplifying mechanical preparation for either the diffusion or alloying process.

Hyper-pure silicon for every need is now available from Dow Corning. If you grow your own crystals from polycrystalline chunk using the Czochralski method . . . if you zone refine polycrystalline rod . . . if you need 1000-ohm centimeter or better resistivity in single crystal P-type — Dow Corning should be on your preferred source list.

Each Dow Corning single crystal rod is checked for resistivity over its entire length. Resistivity and lifetime profiles, like those shown below, are supplied with each crystal.



Write for "Hyper-Pure Silicon for Semiconductor Devices." Address Dept. 8215a.

HYPER-PURE SILICON DIVISION
Address: HEMLOCK, MICHIGAN

Dow Corning CORPORATION

MIDLAND, MICHIGAN

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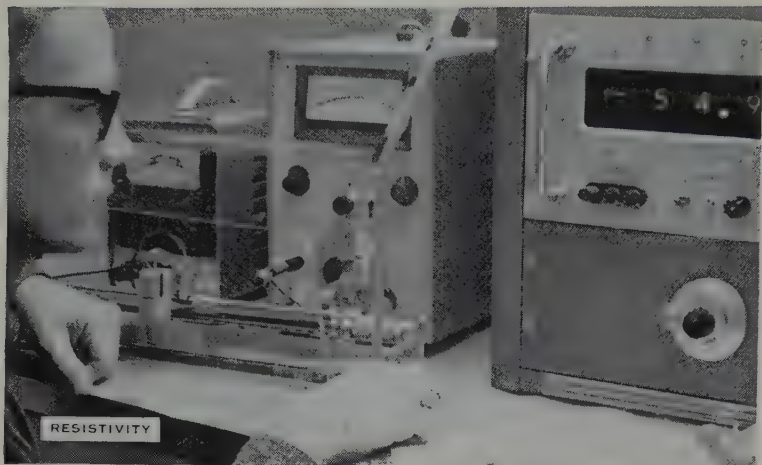
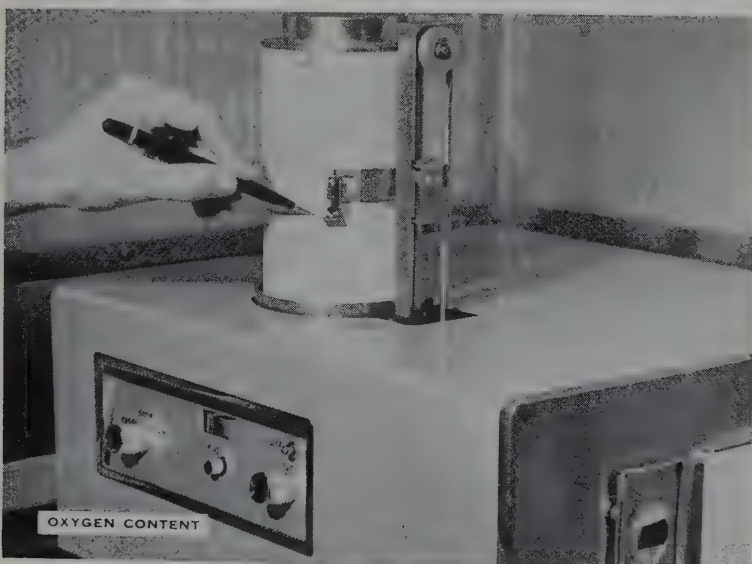
SILICON NEWS from Dow Corning

The Untouchables (Part 3)

Now...Single Crystal Silicon Doped to Your Specification


RESISTIVITY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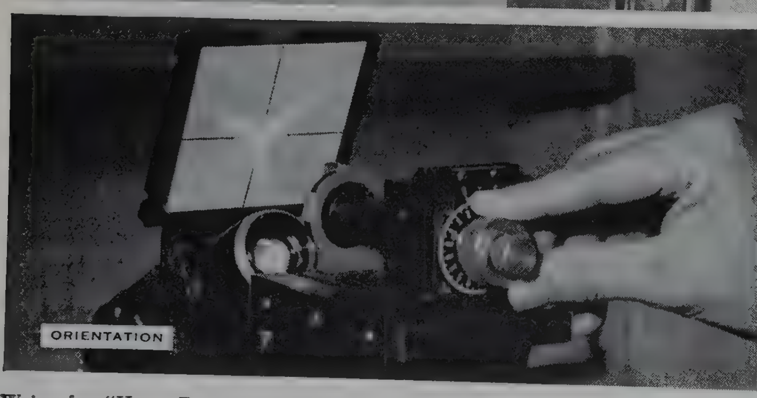

ORIENTATION

Single crystal silicon . . . doped to your specific needs . . . is now available from Dow Corning.

Rigid quality control of Dow Corning Silicon means greater device yield for you! And you achieve uniformity in device characteristics — the result of greater uniformity in characteristics from rod to rod, greater lateral and radial uniformity within each rod.

This high quality is the result of a completely integrated production process — a process that starts with the manufacture of trichlorosilanes and other chemicals basic to silicon production. And at every step of the way, rigid quality control assures the ultimate in quality—purity.

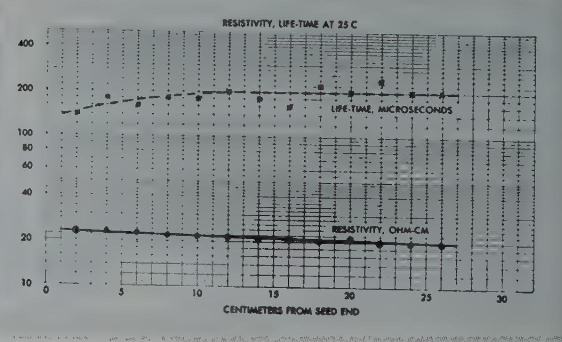
Doped to specification single crystal Dow Corning Silicon contains in the order of 0.1 atoms of minority impurity per billion atoms of P-type material . . . about 0.15 atoms of minority impurity per billion atoms of N-type material.

Low oxygen content of Dow Corning Silicon reduces the undesirable effects on lifetime associated with the diffusion process. Result — few rejects . . . increased device yield! In the picture at left, infrared transmittance at 9 microns is measured to determine oxygen content. Many materials register at pencil point—much higher than Dow Corning Silicon.

Crystal orientation is normally 111, but can be to your specification.

Specify Dow Corning single crystal silicon doped to your requirements. Specific resistivities within narrow tolerances from one to 1000-ohms centimeter P-type . . . one to 400-ohms centimeter N-type. Rod diameters from 3 to 25 mm (1/8″ to 1″) lengths to 250 mm (about 10″).

Whatever your need — polycrystalline rod or chunk; high resistivity P-type single crystal rod; single crystal rod doped to your specifications — Dow Corning should lead your list of sources.



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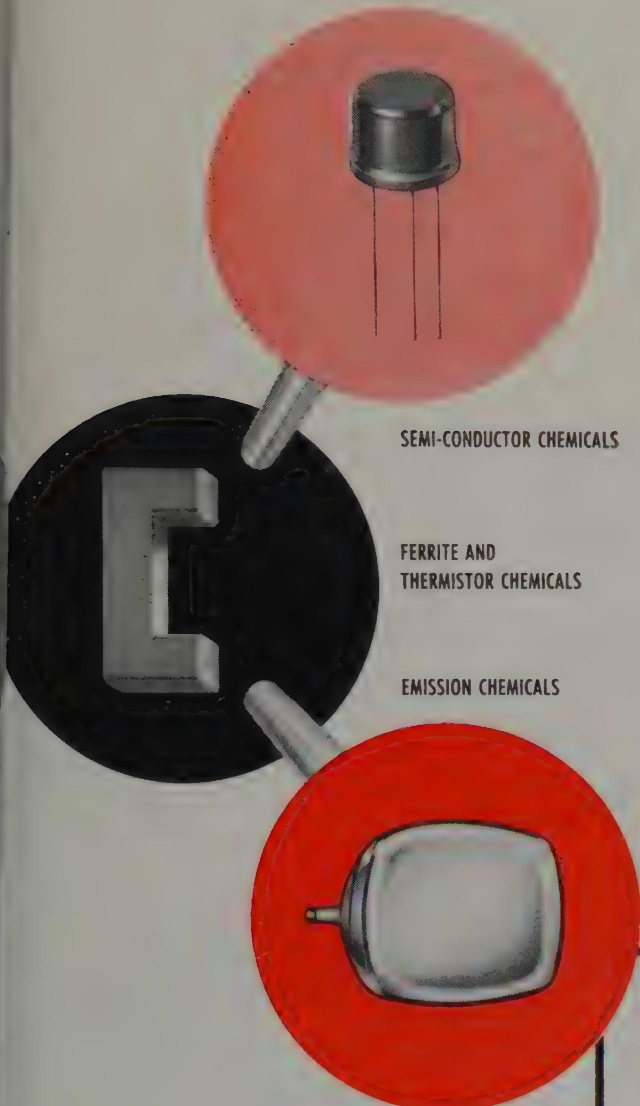
to meet critical electronic manufacturing needs



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- Ammonium Hydroxide
- Ammonium Phosphate
- Antimony Trioxide
- Barium Acetate
- Barium Carbonate
- Barium Fluoride
- Barium Nitrate
- Benzene
- Boric Acid
- Cadmium Chloride
- Cadmium Nitrate
- Cadmium Sulfate
- Calcium Carbonate
- Calcium Chloride
- Calcium Fluoride
- Calcium Nitrate
- Calcium Phosphate
- Carbon Tetrachloride
- Cobalt Carbonate
- Cobalt Oxide
- Cobalt Nitrate
- Ether, Anhydrous
- Hydrochloric Acid
- Hydrofluoric Acid
- Hydrogen Peroxide, 30% and 3% Solution
- Lithium Carbonate
- Lithium Chloride
- Lithium Nitrate
- Lithium Sulfate
- Magnesium Carbonate
- Magnesium Chloride
- Magnesium Oxide
- Manganese Dioxide
- Manganese Nitrate
- Manganese Sesquioxide
- Manganous Carbonate
- Methanol
- Nickel Carbonate
- Nickel Oxide, Black
- Nickel Oxide, Green
- Nickelous Chloride
- Nickelous Nitrate
- Nickelous Sulfate
- Nitric Acid
- Petroleum Ether
- Potassium Dichromate
- Potassium Hydroxide
- iso-Propyl Alcohol
- Radio Mixture No. 3
- Silicic Acid
- Sodium Carbonate
- Sodium Chloride
- Sodium Hydroxide
- Sodium Phosphate Dibasic
- Strontium Carbonate
- Strontium Nitrate
- Sulfuric Acid
- Toluene
- Trichloroethylene
- Triple Carbonate
- Xylene
- Zinc Chloride
- Zinc Nitrate
- Zinc Oxide

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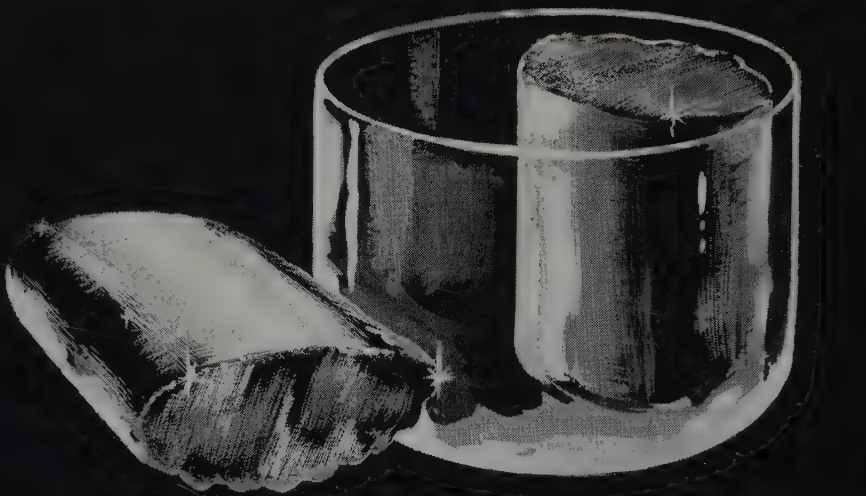

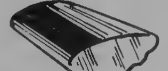

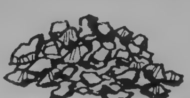

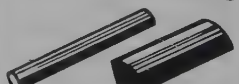

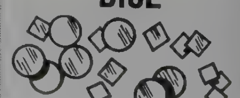

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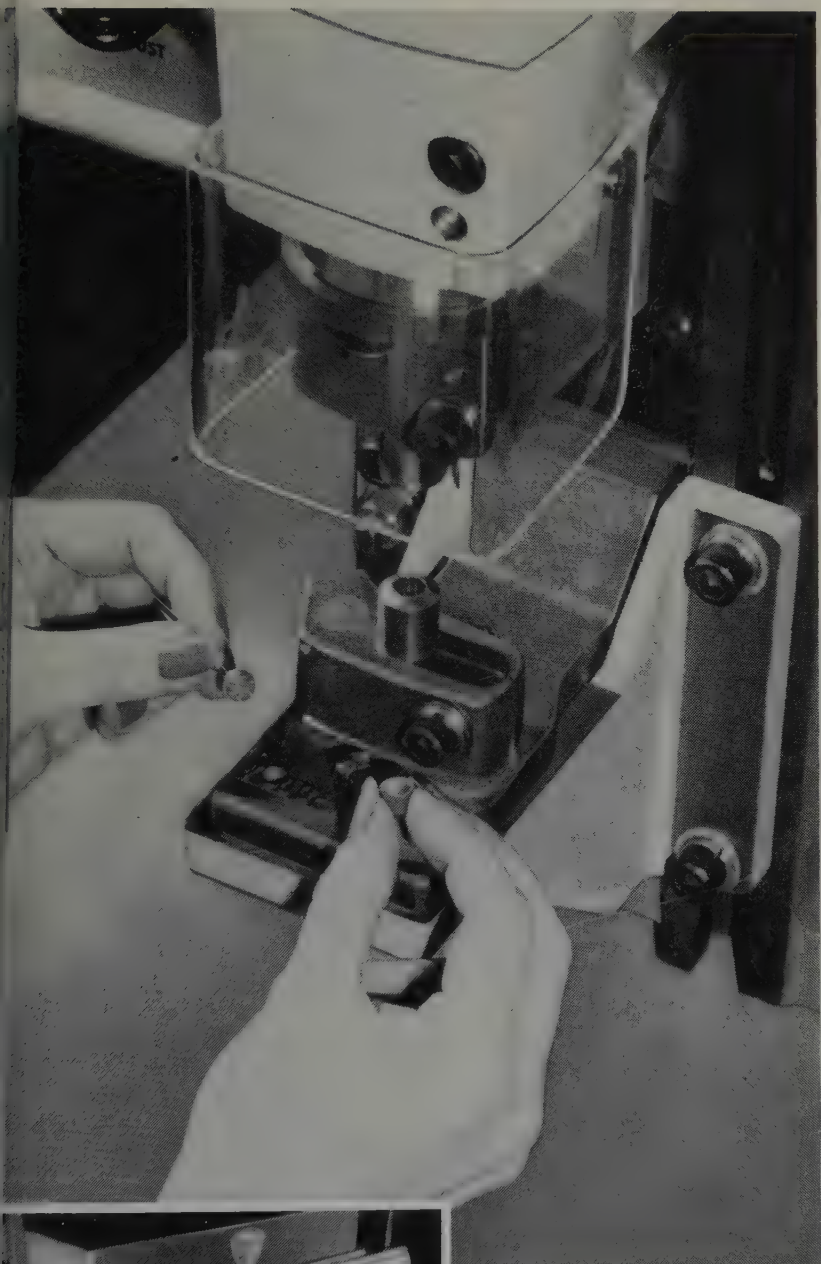

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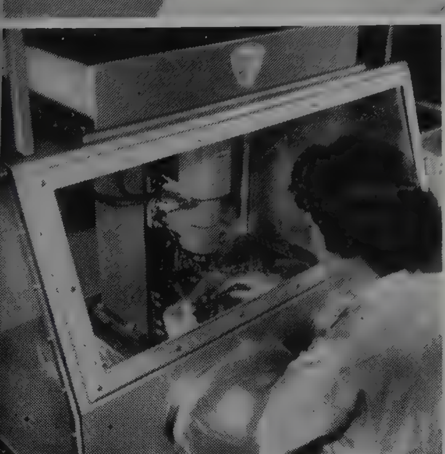

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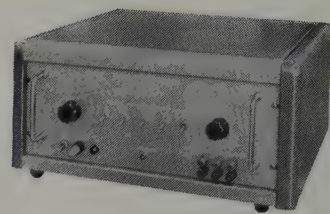

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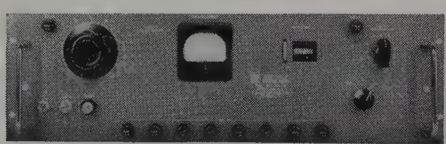

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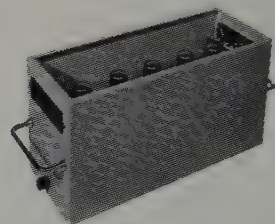

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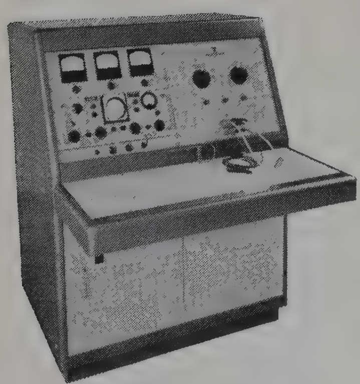

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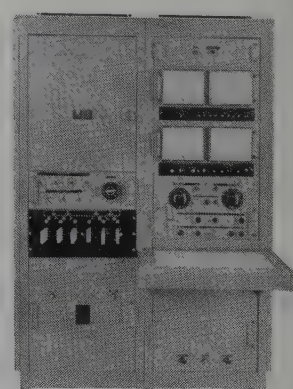

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Book

TITLE: Encyclopedia on Cathode-Ray Oscilloscopes and Their Uses

AUTHOR: John F. Rider, Seymour D. Uslan

PUBLISHER: John F. Rider, New York

The Encyclopedia on Cathode-Ray Oscilloscope and Their Uses is a massive book containing a wealth of information on the design, construction circuitry and use of the oscilloscope. This book is the second edition of an earlier work that has long been an industry reference.

The *Encyclopedia* contains twenty-three chapters grouped in five sections. The first section deals with the theory of operation of oscilloscopes in general. The first chapter starts with the basic cathode ray tube and discusses types and structures. This is followed by a highly understandable discussion of focusing and deflection. Although very little field theory is used to describe electron beam displacement, the discussions are succinct and remarkably clear. The great wealth of excellent diagrams and illustrations do much to aid in the presentation.

Section II next discusses oscilloscope circuitry and operation. Here the material is presented in a non-mathematical but highly undertsandable form. A chapter is devoted to horizontal and vertical amplifiers. Another chapter deals with time bases. There are chapters devoted to synchronization and power supplies as well as maintenance and special purpose tubes.

The third section deals with the applications of the oscilloscope. Here may be found almost every conceivable use of the instrument from pulse analysis to RF alignment and medical applications. Chapter XVIII is a veritable book in itself and describes the use of the oscilloscope in TV receiver observations.

The fourth and fifth sections of the Encyclopedia are devoted to waveform analysis and commercial oscilloscope schematics. Again a fund of information is presented in the form of charts, photographs, diagrams and drawings.

The Encyclopedia on Cathode-Ray Oscilloscopes and Their Uses is perhaps the best, most concise and up-to-date work on the subject. In no other single book can the variety of design, analysis and application information on the oscilloscope be found. The text and presentation are excellent in all respects and are aided in no small part by the amount and high quality of the illustrative material. This encyclopedia may certainly be considered a basic laboratory manual on the cathode ray oscilloscope.

Reviews . . .

TITLE: Transistor Circuit Analysis and Design

AUTHOR: Franklin C. Fitchen

PUBLISHER: Van Nostrand, New Jersey

Transistor Circuit Analysis and Design is a textbook dealing with the applied use of transistors. This book presents only that amount of theoretical background necessary to understand the practical application of the transistor.

The first two chapters provide an introduction to the transistor in terms of circuit parameter definitions and semiconductor physics. The latter material is presented in an unusually clear manner with excellent line drawings illustrating the movement of the electrons and holes. The energy band concepts are illustrated and the *p-n* diode is presented as an introduction to the transistor.

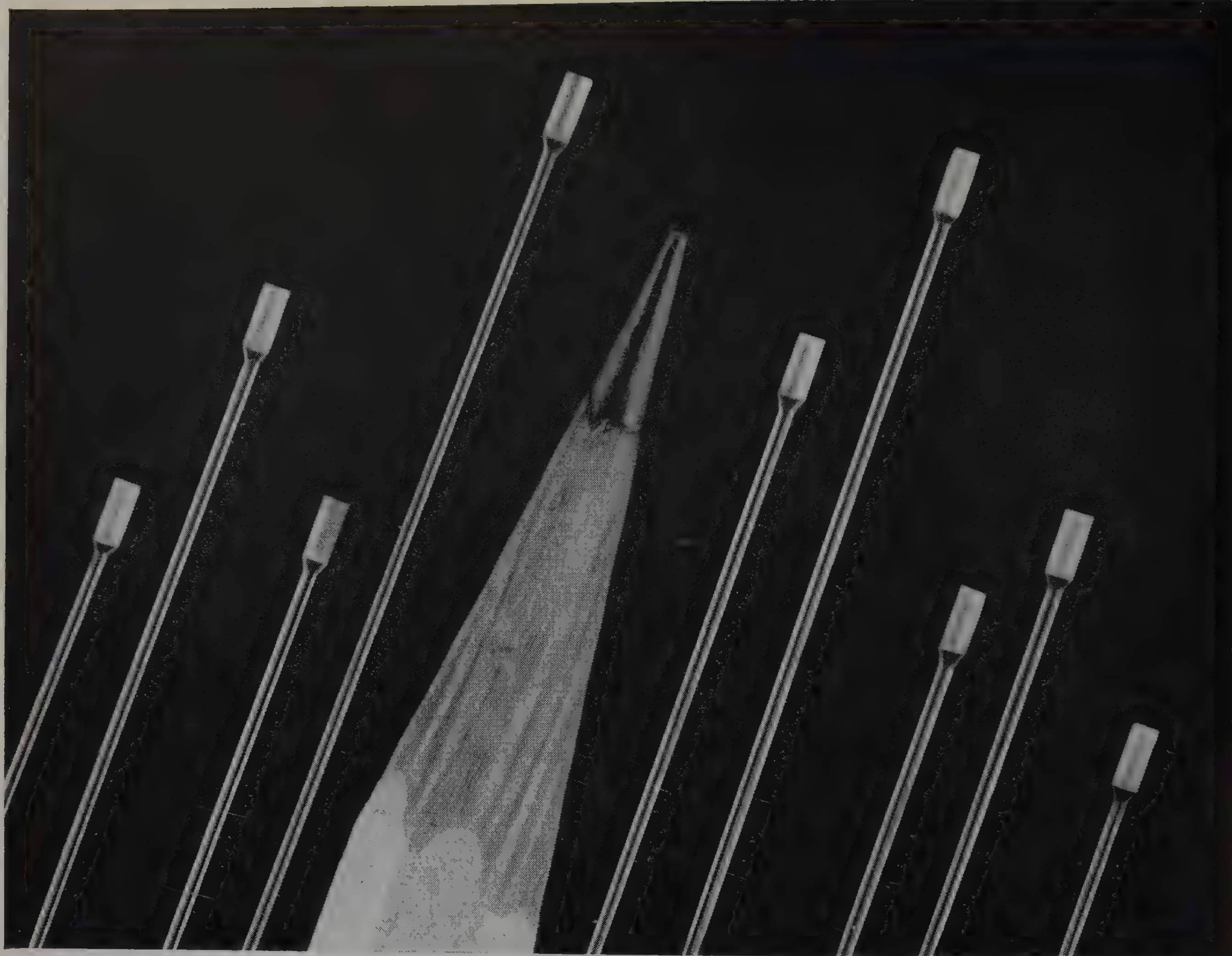
Chapter III considers the transistor as an active element in a circuit. This chapter, entitled *"The Operating Point,"* is an exceptionally lucid, clear presentation of both bias consideration and stability factors. A great many examples of the methods of bias stabilization are discussed. Two operating point drifts, the collector current to supply voltage and the collector current to alpha factors (entitled M and N here) are defined and tabulated together with other biasing equations in table 3-1.

Chapters IV and V develop the transistor equivalent circuit and the single stage amplifier. The presentation in terms of the hybrid parameters is excellent. Equations are collected and tabulated throughout the chapter (IV). Parameter variations with respect to temperature are presented graphically. Low, medium and high frequency gain equations are considered and typical illustrative examples are given to clarify amplifier design methods.

A great variety of additional topics are covered in the remaining chapters of the book. Multistage amplifiers, feedback, communications amplifiers and pulse circuits are typical. Three appendices containing selected transistor characteristics and various circuits and parameter conversion tables complete the book.

Transistor Circuit Analysis and Design is an excellent first book on transistors. The approach, stressing direct application of transistors, will make this book invaluable as a working tool. The material is carefully chosen and adequately referenced. The clarity of presentation is unusually good with the practical design aspects always in mind.

By Stephen E. Lipsky



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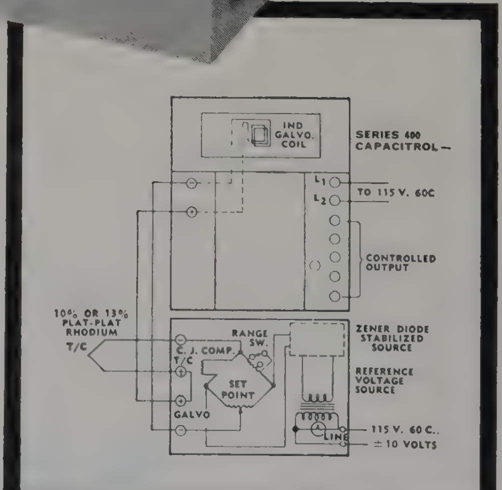

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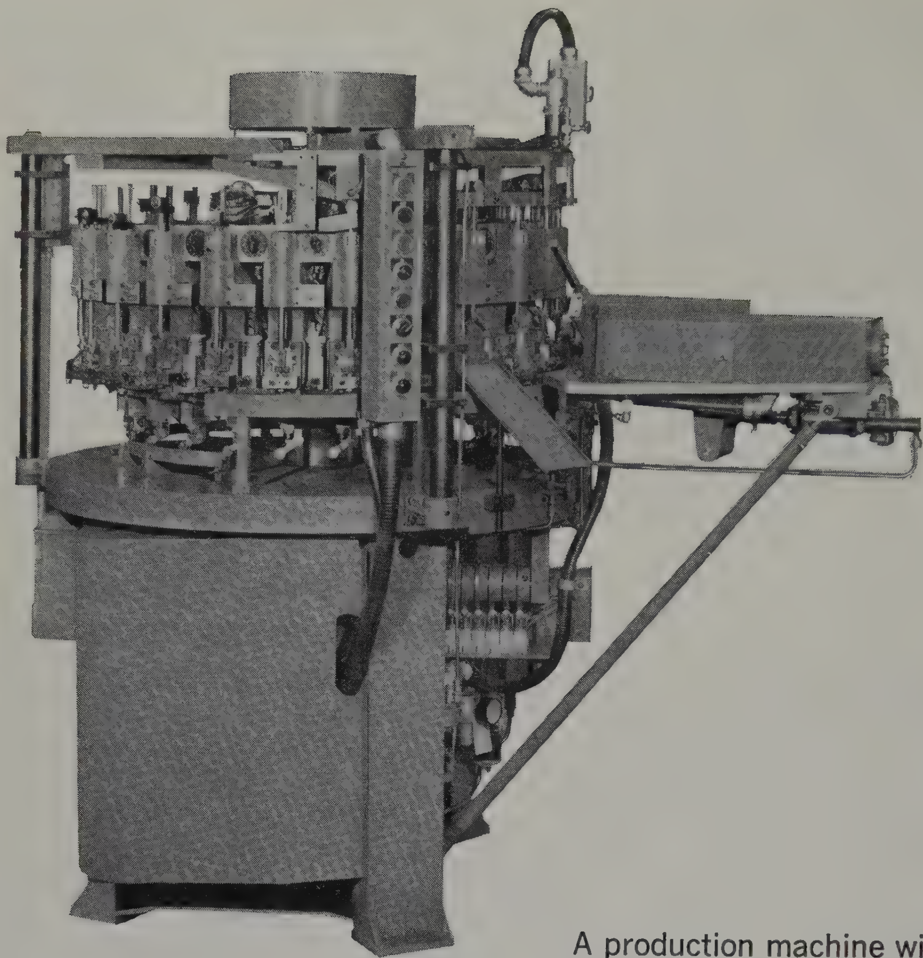

Editorial . . .

Electroluminescent Devices

One class of solid state phenomena, the technical and practical importance of which has been growing steadily in the past decade, is that based on the luminescence effect. This consists of the emission of light by a crystal under the excitation by another radiation of sufficiently high frequency to produce the effect. The luminescence is called fluorescence if it occurs at the onset of the excitation (about 10^{-8} sec. later) and terminates with the latter. On the other hand it is called phosphorescence if it occurs after a certain delay and persists for time intervals of the order of fractions of seconds or longer after the excitation is ended.

The technical applications of luminescence are extremely varied and in some cases obvious. To mention a few, one may refer to cathode ray tubes, fluorescent tubes, display panels, light amplifiers, etc. Fluorescent crystals have been used recently to produce self-coherent light beams.

The luminescence effect may be produced by radiation pumping, by electron impact, and by *a-c* electric fields produced in the bulk of the crystal. The latter effect, called electroluminescence, was discovered in France in 1936, but has been studied to any great extent only in the past decade. At present the electroluminescent devices possess brightness of the order of that of fluorescent tubes.

A typical cell consists of a zinc sulphide crystal with activator impurities consisting of ions of Cu, Na, Li, Ag, and coactivator impurities consisting of ions of C1, A1, Ga, In. A crystal with a thickness of the order of 50μ is mounted between two electrodes, one of which is transparent. Under the application of an external *a-c* voltage V of frequency varying up to the order of 100 *kc*, a light radiation of spontaneous emission type is produced.

The mechanism of production may take various forms: the activator ions produce filled levels near the top of the valence band and the coactivator ions produce empty levels near the bottom of the conduction band. Under the application of the *a-c* potential, electric fields of the order of 10^6 V/m are created in the crystal. These may accelerate conduction electrons sufficiently to produce hole-electron pairs which are trapped at the coactivator levels. During the half-cycle of decreasing fields the traps are emptied and recombination occurs with emission of light. As a result the latter appears to be modulated at a frequency twice that of the excitation. Its average brightness varies as $\exp(-b/\sqrt{V})$ where b is a quantity depending on the material, the impurities, the frequency of excitation, etc.

At constant value of V the brightness increases asymptotically with the frequency up to about 10 to 100 *kc*. If the applied voltage is a square wave the light appears as pulses of rise time about 0.2 μsec and decay time inversely proportional to the excitation frequency. For example, one may have decay times of the order of 20 μsec at $f = 2$ *kc*, 10 μsec at $f = 10$ *kc*, etc. These characteristics clearly indicate the importance of electroluminescent devices for technical applications.

A High Speed Analog To Digital Converter

CARL DAVID TODD*

Analog voltages may be described by a series of binary pulses, thus allowing easier data handling and recording. A complete analog to digital converter system capable of describing a given input voltage within 25 microseconds is presented in detail. The philosophy and techniques of the "put and take" approach to decision making are discussed to give the necessary background to understand the circuit function.

ANALOG TO DIGITAL CONVERTERS are used in telemetry systems to change a signal voltage from its analog form to a series of binary pulses. This allows easier data handling and recording.

The basic form of an analog to digital converter is illustrated in *Fig. 1*. A timing circuit which may be synchronized by a clock pulse adjusts a binary to analog reference voltage until it is equal to the analog input. The comparator feeds a control signal back to the timing circuit to establish the condition of equality.

Two basic approaches are possible for the timing circuitry. The first approach is exemplified by a simple multi-stage binary counter with the output of each stage controlling a binary bit in the binary to analog reference. Thus, the reference voltage would be zero at the beginning and then increase in increments determined by the smallest bit of the reference. As soon as the reference voltage became equal to the analog input voltage, the comparator would generate a voltage which would prevent further progression of the counting cycle.

To perform an analog to digital conversion within a period of time of some 30 microseconds would require a clock rate of approximately 4 megacycles for a conversion accuracy of one percent. While binary counters operating at these frequency rates are quite feasible, generating an accurate reference voltage and performing the comparison at this speed would be extremely difficult.

A second approach to analog to digital conversion which is capable of high speed operation is the "put and take" or "half-add-subtract" technique. In this approach, the reference voltage is first set to one half of full scale and a comparison made with the unknown voltage. If the reference value is high, a comparison is then made at one quarter of full scale voltage etc. More will be said about this approach later. For now it is only necessary to understand that less decisions are necessary for a given result in conversion accuracy and hence for a given rate of decision, less time will be required for the "put and take" approach than for the straightforward counter approach.

Analag to digital converter systems using the "put and take" approach have been described in several articles.[1,2] It is the purpose of this article to present a complete design of an analog to digital converter in much more detail than is currently available in the literature.

"Put and Take" Approach

In the "put and take" technique the unknown voltage is first compared with one half of the full scale voltage and a decision made whether to decrease or increase the reference voltage by one fourth of the full scale voltage. A new comparison is then made to decide whether to add or subtract ⅛ of the full scale voltage.

This process continues until the desired accuracy of conversion is obtained. A single decision could give a resulting error as high as 25 percent of full scale. A two decision process could have an error as large

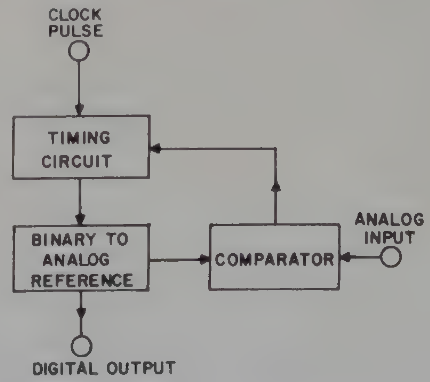

Fig. 1—Basic form of an analog to digital converter.

*Senior Staff Engineer, Special Products Operations, Hughes Semiconductor Division, Newport Beach, California.

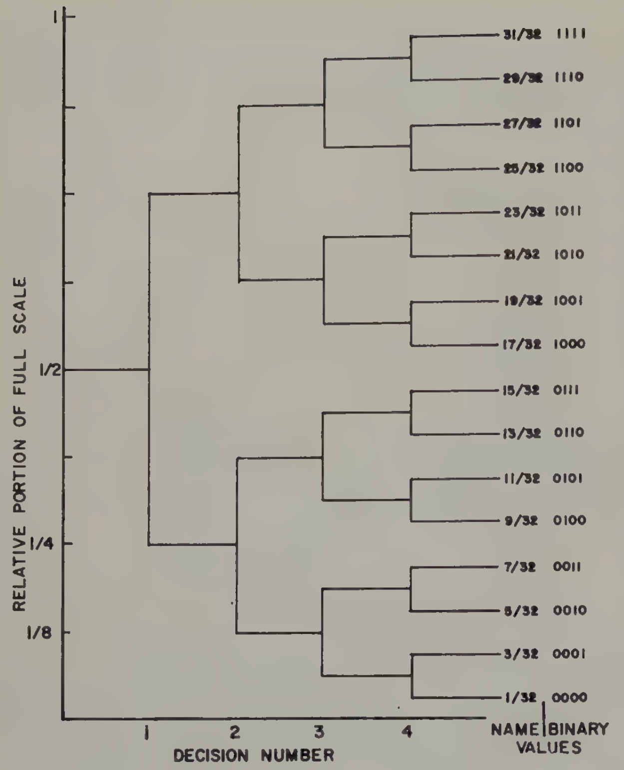

Fig. 2—"Put and Take" method for a 4-decision system.

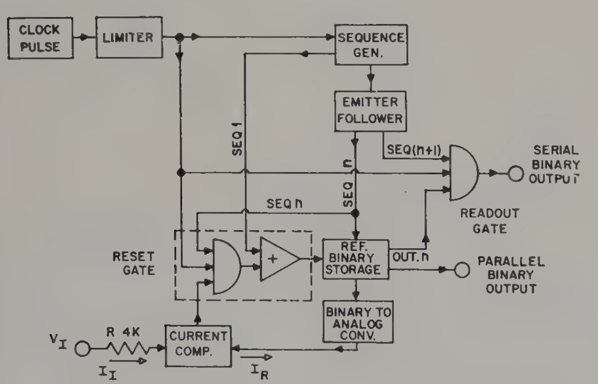

Fig. 3—Simplified block diagram—ADC.

as 12.5 percent of full scale and so on. Only six decisions are required to obtain an accuracy better than one percent of full scale.

Figure 2 shows the sixteen possible operating paths for a four-decision system. For an n-decision system, there will be 2^n possible paths or 2^n posssible answers. The maximum possible error due to the approach alone will be:

$$\text{M.P.E.} = \frac{100}{2^{(n+1)}} \text{ percent.}$$

It is important to distinguish between the voltage at which the decision is made and the value which we assign a "name" to. For example, assume the simplest case—that of a single-decision system. Our reference is set at one half full scale. By comparing the unknown input voltage with the reference, a decision is made as to the larger voltage.

If the input voltage is larger than one half of full scale, we do not know how much larger. We only know that it is greater than one half of full scale and less than or equal to full scale. In order to reduce the maximum possible error (percent of full scale) which may occur as a result of our decision, we *say* that the input voltage is ¾-full scale.

On the other hand, if the input voltage is less than the half-scale reference, we only know that it lies somewhere between zero and half-scale. Again to reduce the maximum possible decision error, we *say* that the input is ¼ of full scale.

For an n-decision system, therefore, we have 2^n name values; one of which is used to describe the input voltage. The lowest name value is $1/2^{(n+1)}$ of full scale and the highest name value is $(2^{(n+1)} - 1)/2^{(n+1)}$ of full scale.

Calibration of the full-scale value is accomplished by applying an input voltage equal to the highest voltage at which a decision may be made. For the 4-decision system of *Fig. 2*, this is 15/16 of full scale; for the general case this is $(2^n - 1)/2^n$.

Analog To Digital Converter

A highly simplified block diagram of the analog to digital converter to be described in this article is shown in *Fig. 3*.

A clock pulse is injected into the limiter which is used to give a constant output pulse for a wide range in input voltage. The use of this switching stage also gives a low output resistance in the condition of zero output voltage as required by the diode gating circuits.

The clock pulse as obtained from the limiter is fed into the sequence generator which develops eight sequentially related negative pulses. The sequence pulses are then fed into emitter followers.

A given sequence pulse *sequence n*, turns on a corresponding flip-flop FF_n in the binary store whose output controls the reference current, I_R, developed by the binary to analog converter.

The reference current, I_R, is compared with the current I_I, flowing as the result of the application of the input voltage, V_I. If the magnitude of I_R exceeds that of I_I, a negative voltage is generated by the comparator and is fed into the reset gate.

If the output voltage of the comparator becomes negative during the time period of *sequence n*, a negative voltage will be developed by the reset *and* gate during the period the clock pulse is negative as illustrated by the simplified voltage waveforms of *Fig. 4*. This negative voltage then resets FF_n in the binary reference storage.

If I_R were less than I_I, no reset signal would have been developed and the reference binary flip-flop FF_n would have remained "set" and thus produce an output voltage, *output n*. This output feeds the readout *and* gate which, upon the application of the *sequence*

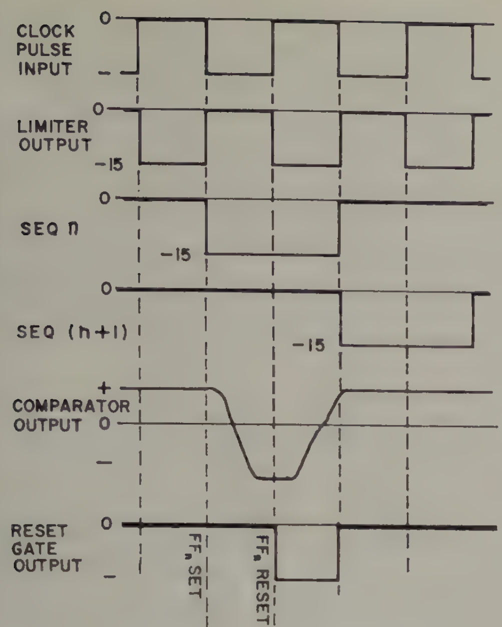

Fig. 4—Simplified voltage waveforms.

$n + 1$) and a negative clock pulse, will produce an utput pulse.

Upon the generation of *sequence 1* all flip-flops exept for FF_1 reset. *Sequence 1* sets FF_1 which comares the input voltage V_I with ½ full scale voltage. f V_I is greater than ½ scale, FF_1 remains set. If, on he other hand V_I is actually less than ½ scale, FF_1 vill be reset.

Sequence 2 pulse then sets FF_2 in the binary refernce storage and causes a readout of FF_1. If FF_1 renained set (V_I greater than ½ scale) an output vould be produced by the readout gate.

When FF_2 is set, the effective reference voltage is ncreased by ¼ scale. If FF_1 remained set, V_I is now compared against ¾ scale (or if FF_1 had been reset, against ¼ scale), as before, if V_I is greater than I_R, FF_2 will remain set; if I_I is less than I_R, FF_2 will be reset by the reset gate.

This procedure is continued by adding 1/8, 1/16, 1/32, 1/64 and 1/128 full-scale values to the reference and a decision is made whether to keep or reject the newly added value in accordance with the "put and take" approach described earlier.

A flip-flop stage in the reference binary storage is "read" by the readout gate upon the application of the sequence pulse which follows the one during which it was set. This gives a serial pulse description of the input voltage.

If parallel output is desired, it is only necessary to connect to the binary reference output directly. A gating signal may be obtained from the sequence generator to allow readout after the cycle has been completed. We will now look at each individual component in the block diagram in more detail.

Clock Pulse Circuitry

Timing and synchronization is controlled by an

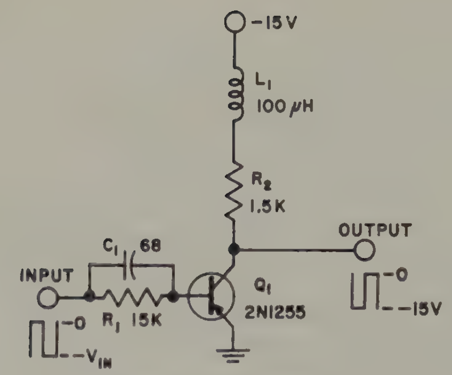

Fig. 5—Limiter.

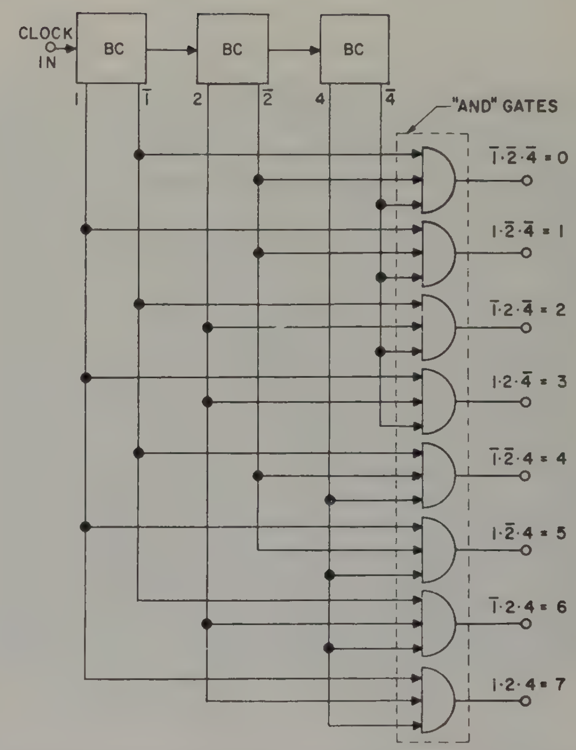

Fig. 6—Basic block diagram of the sequence generator.

input clock pulse having a relatively square waveform at a repetition frequency from a very slow rate up beyond 250 kilocycles per second.

A single stage limiter as shown in *Fig. 5* is used to produce a constant amplitude clock pulse over a range of input voltage from about 7 to 50 volts. If large positive peaks are present in the waveform driving the input, a shunt diode should be connected between the base and emitter of Q_1. Q_1 is driven alternately into saturation and cutoff.

The limiter also presents a low resistance path to ground when the output is zero. This is important for proper operation of the reset and readout *and* gates.

Sequence Generator

The sequence generator develops eight sequentially related negative pulses which are used for the timing

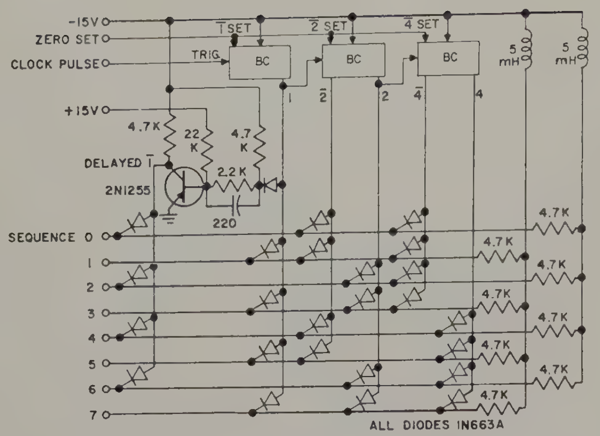

Fig. 7—The sequence generator.

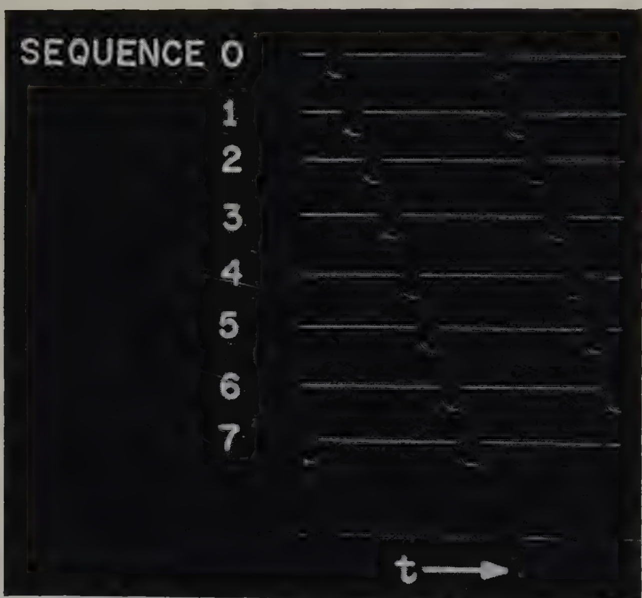

Fig. 8—Sequence generator output waveforms.

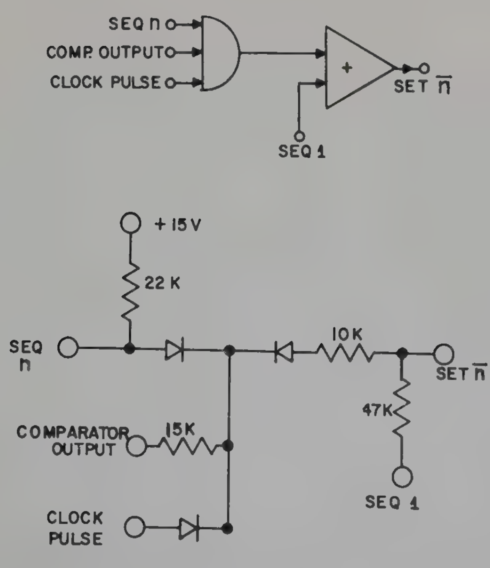

Fig. 9—Simplified reset gate schematic.

control of the functional circuits. The block diagram of the sequence generator is shown in *Fig. 6* and its schematic diagram is given in *Fig. 7*.

The eight output voltage waveforms are illustrated in *Fig. 8* for a repetition rate of 250 *kc*. For further detailed information, the reader is referred to an earlier article[3] describing the sequence generator. As mentioned in the original article, an emitter follower was added to each output of the sequence generator to give a lower output resistance. A 10 kilohm load resistor was included in each emitter.

Reset Gate

Any time the added value produced by setting a flip-flop in the binary reference storage causes the magnitude of the reference current, I_R, to exceed that of the input current, I_I, which results from application of V_I, a reset signal must be generated to return the flip-flop to its original or reset state. The voltage necessary to cause reset is generated by the comparator but must be controlled by the reset gate. The simplified schematic of the reset gate in the form of a single unit is shown in *Fig. 9*.

In order to produce a negative voltage at the output of the *and* gate for resetting, it is necessary that a negative voltage appear at all three input terminals. Thus, flip-flop FF_n may only be reset during the period *sequence n* if a negative voltage is produced by the comparator during the half period of the sequence pulse when a negative clock pulse is present. This action is also illustrated in *Fig. 4*.

After a cycle has been completed and a voltage has been digitized, it is necessary to reset all flip-flop stages in the binary reference storage before the next cycle begins. Total reset may not be accomplished during the period *sequence* 0, since this is the time FF_1 is being read.

Reset may be performed during the period *sequence 1* for all flip-flops except FF_1. It is neither necessary nor desirable to reset FF_1 since the cycle begins with FF_1 in the "set" state.

The complete schematic diagram of the reset gate is shown in *Fig. 10*.

Reference Binary Storage

The memory of past decisions made during the process of digitizing an analog voltage is retained in the reference binary storage. Seven identical binary flip-flops of the form shown in the schematic diagram of *Fig. 11* are used to store the seven bits of information. The flip-flops are set by the rising portion of their corresponding sequence pulses and may be reset upon the receipt of a negative current from the reset gate. Diode CR_1 provides a discharge path for capacitor C_3 when the sequence pulse returns to zero. Without this diode, the flip-flop would be reset unintentionally.

The output is taken from the collector of Q_1, and thus, a negative output voltage is available in the "set" state. This output feeds the readout gate for

serial output or may provide an output in parallel form. Connection to the collector of Q_2 may provide the complement of the output if desired.

Binary To Analog Converter

The binary to analog converter receives its controlling input from the binary reference storage and produces an analog current corresponding to the digital input. The analog to digital converter may be thought of as a servo loop. In such a case, the binary to analog converter is, in effect, the feedback path since the input is reconstructed from the output and is then compared by the comparator.

The schematic diagram of the seven bit binary to analog converter is shown in *Fig. 12*. Diode gating circuits switch the current sources on and off upon command of output voltages from the binary reference storage.

The seven reference currents are derived from a well-regulated 128-volt power source fed through an appropriate precision resistor. Since the output voltage is very low, the current is determined almost entirely by the supply voltage and series resistor.

The analog to digital converter described in this article was designed for a 1.28 milliampere full scale (5.12 volts applied to an input resistor of 4 kilohms) input and thus the individual current sources are 0.64 milliampere, 0.32 milliampere, etc, down to 10 microamperes for the seventh stage.

The full-scale value of 5.12 volts was chosen for simplicity in testing and describing the prototype model. This may be changed by modifying the input resistor, *R*. The full-scale voltage will be $1.28 \times 10^{-3} \times R$.

All of the diodes used in the gating circuits must be capable of relatively high speed operation in high resistance circuits. The Hughes HD5000 silicon ultra fast computer diodes have the low capacitance and fast recovery required for the *or* gate diodes CR_1 through CR_7.

Diodes CR_8 through CR_{14} may also be type HD5000 although somewhat better performance was obtained using the Hughes type 1N663A silicon computer diode. The 1N663A has a slightly higher value of capacitance which is utilized to overcome the shunt wiring capacity in the high resistance circuitry.

Comparator

One of the most critical elements in the analog to digital converter system is the comparator which must make the necessary decisions at a high rate of speed. To add to the problem, the comparator undergoes severe overload as the various reference currents are switched in and out. The worst case is for the condition where the analog input voltage is near zero. The first step places a half-scale current into the comparator. It is fortunate that if such an overload is present, more than one period of time is available before the comparator must fully recover from the overload. It is necessary that no transient ringing be de-

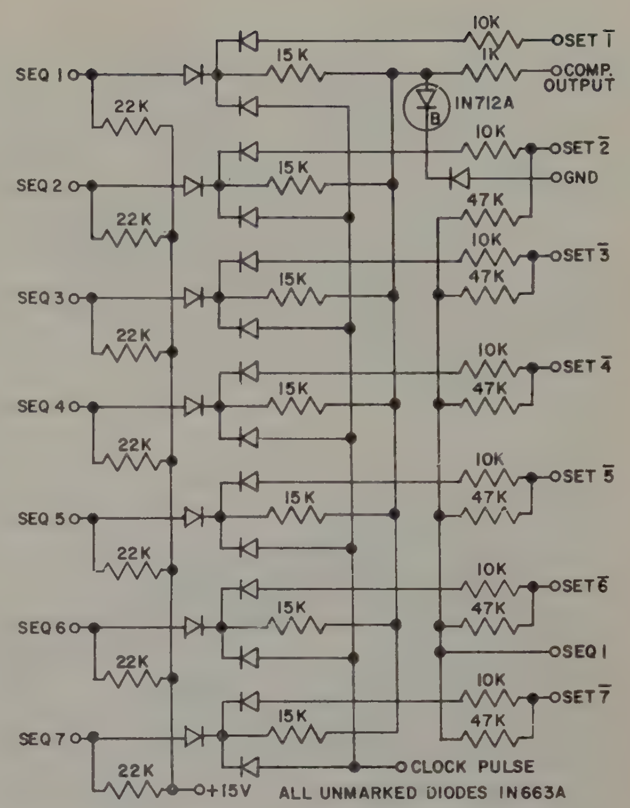

Fig. 10—Reset gate.

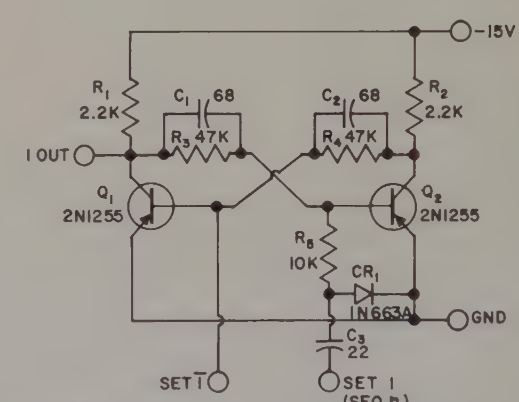

Fig. 11—Flip-flop used in the reference binary storage.

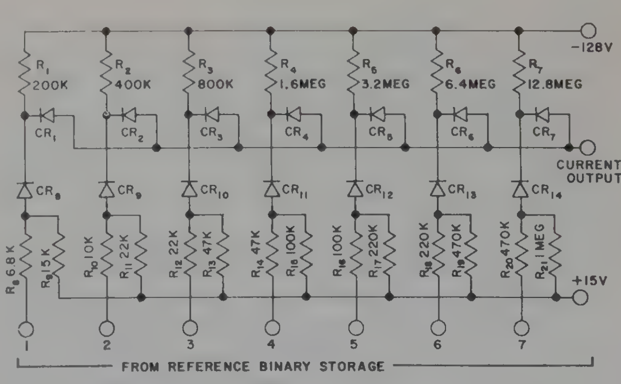

Fig. 12—Binary to analog converter.

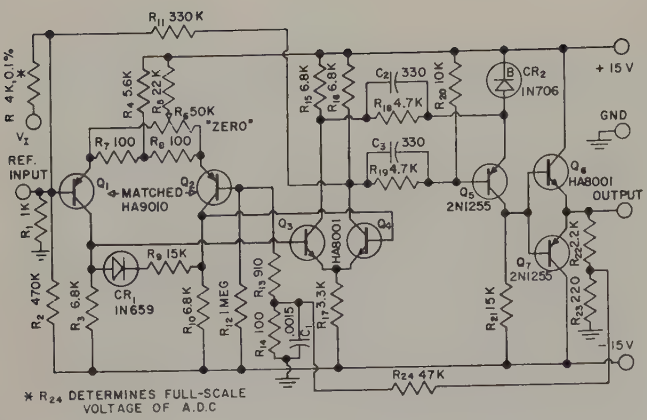

Fig. 13—A high speed DC comparator.

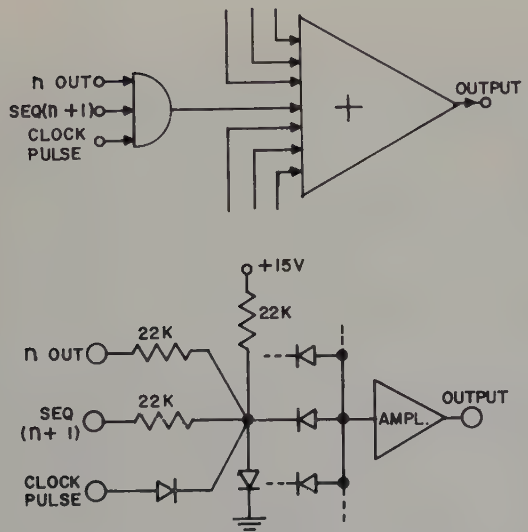

Fig. 14—Simplified schematic of the readout gate.

veloped with the output oscillating between a positive and a negative value.

Equivalent input zero drift was held to about ± 1 error and to allow performance at elevated temperatures.

The performance of the comparator illustrated schematically in *Fig. 13* is excellent. Measured recovery for a 65 times overload was less than 1.5 microseconds.

Equivalent input zero drift was held to about ± 1 millivolt over a wide temperature range by using matched transistors for the first differential stage.

This comparator is described in detail in another paper by Todd and Morishita.[4] For a theoretical discussion of comparison, reference No. 5 should be consulted.

Readout Gate

After the flip-flops in the binary reference storage have had the opportunity to be set, their state may be read out by some means. One approach would be to complete the process of analog to digital conversion and then read the memory in a serial or parallel manner. For serial readout it is actually preferable to read the memory stage as soon as the decision as to its state has been made. Thus, since the conversion and readout operations are performed concurrently, each function has more time available for a given requirement of total cycle period.

For a given flip-flop, FF_n, in the binary reference storage, the final decision as to its state for a given conversion is made during the period *sequence n*. The readout function of FF_n may then be asccomplished during the time period *sequence* $(n + 1)$.

The schematic diagram for one unit of the readout gate is shown in *Fig. 14.* The circuit is a simple three-input *and* gate. If no voltage of flip-flop FF_n is in the reference memory, the *sequence* $(n + 1)$ pulse is insufficient to overcome the forward bias of diode CR_n, (since the sequence voltage is always somewhat less than 15 volts), and hence no output is produced.

If, on the other hand, a negative voltage is present at the *n output* terminal, a negative output may be produced during the portion of the period *sequence* $(n + 1)$ in which the clock pulse is negative.

The outputs of the seven sections of the readout gate feed an *or* gate to yield a serial output at the *output* terminal.

The complete schematic of the readout gate is shown in *Fig. 15.* The two transistors Q_1 and Q_2 are used to amplify the output of the readout *and-or* gate and to properly shape the waveform of the output pulses.

Packaging

All of the functional circuits except for the clock pulse amplifier were constructed as plug-in modules. The sequence generator and the eight emitter followers were mounted in one can and the *d-c* comparator in another.

To simplify the wiring, the binary to analog converter and the readout gate were placed in the same can as were the reset gate and the reference binary storage.

No real effort was made to achieve the ultimate in compactness. Yet the same 330 components including 39 transistors and 99 diodes were packaged in a cabinet measuring 9″ x 5½″ x 5½″.

Photographs of the finished analog to digital converter are shown in *Figs. 16* and *17*.

Interpretation

Proper interpretation of the output word is necessary to yield the optimum accuracy. As described in the earlier discussion on the "put and take" approach, certain "name values" are available. For the seven-decision system, 128 name values are available.

To arrive at the name value from the binary word describing the analog input voltage, it is necessary to add the display value as given in Table 1 for each output pulse present, and to this value add an additional voltage corresponding to $\frac{1}{2}^{(n+1)}$ of full-scale

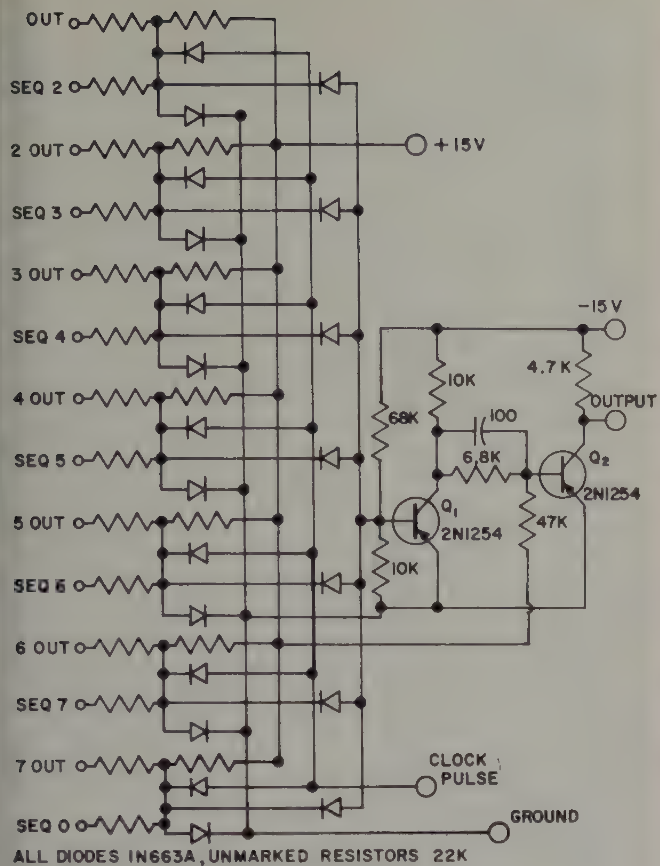

Fig. 15—Readout gate.

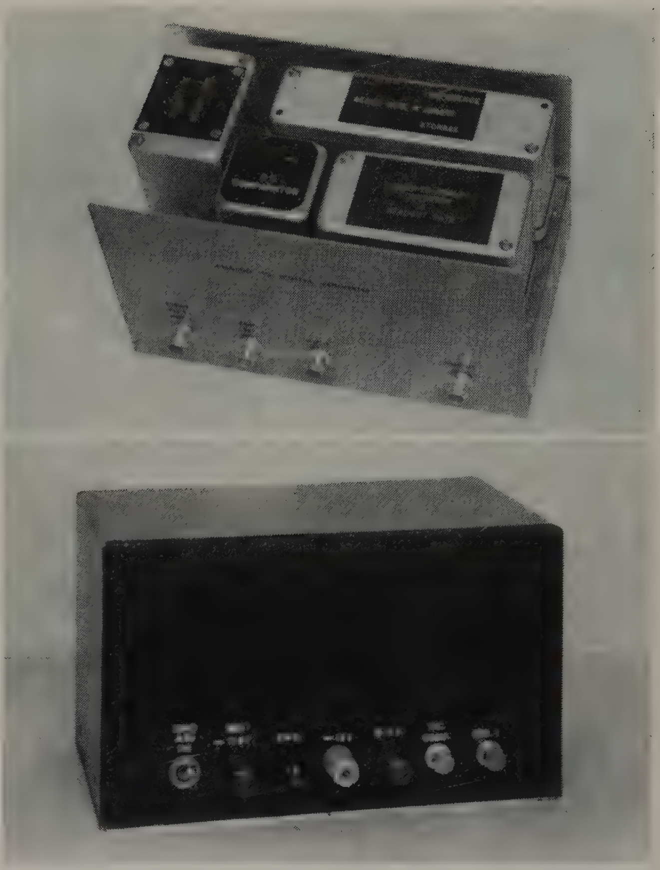

Fig. 16—Top and rear views of the completed converter.

voltage or in the case of the prototype model, 0.02 volts.

Table 1. Display Values for Interpretation of Binary Output.

Output	Fractional F.S. Value	Value (5.12V F.S.)
1	1/2	2.56V
2	1/4	1.28
3	1/8	0.64
4	1/16	0.32
5	1/32	0.16
6	1/64	0.08
7	1/128	0.04

Name value = Sum of display values for pulses present + 0.02V.

Performance

The performance of the sequence generator and the *d-c* comparator has been described in previous articles[1,2] and hence will not be discussed here.

Fig. 18 illustrates several voltage waveforms appearing at various points in the converter circuit. As a typical case, the events surrounding *sequence n* and FF_n are shown for n equal to 3. Two possible conditions are illustrated. Photographs (a) through (g) of *Fig. 18*, illustrate the voltage waveforms where the *sequence 3* pulse sets a ⅛-scale reference voltage only to find that this is higher than the input voltage and thus must be removed.

Fig. 18 (*a*) is the *sequence 3* pulse, (*b*) is the waveform appearing at the input of the comparator, and (*c*) shows the comparator output voltage waveform. The action occurring during time intervals *sequence 1* through *sequence 0* are also shown in *Fig. 18* (b) and (c). Note that when during *sequence 1* a ½-scale

Fig. 17—The completed analog to digital converter.

reference is applied, a negative voltage appears at the input of the comparator thus indicating an excessive reference voltage. The same action occurs during *sequence 2* and *sequence 3* as ¼-scale and ⅛-scale reference voltages are applied.

When *sequence 4* acts to apply the 1/16-scale reference, the comparator remains positive thus signifying that the *d-c* input voltage is slightly greater than 1/16-scale (0.32 volts) but less than ⅛-scale (0.64 volts). When *sequence 7* acts to apply 1/128-scale reference, the comparator input is again driven negative and thus FF_7 must be reset.

The action of the reset gate is illustrated by the waveform shown by *Fig. 18* (*d*). This waveform is taken at the summing junction ahead of the diode and 10 kilohm resistor supplying the reset signal to FF_3. Note the sharp negative spike which occurs during the last half of *sequence 3*. This is the pulse which resets FF_3. The resetting action of *sequence 1* is not shown in *Fig. 18* (*d*) since this reset signal is applied to FF_3 directly.

Fig. 18 (*e*) illustrating the output voltage waveform of FF_3 shows how FF_3 is set for the first half of *sequence 3* but is then reset.

Flip-flop FF_3 is read out during the time interval *sequence 4*. Since FF_3 was reset, no output corresponding to FF_3 appears in the final output waveform of *Fig. 18* (*g*).

Photographs (*h*) through (*n*) of *Fig. 18* illustrate the second condition where the input voltage is greater than ⅛-scale. Thus FF_3 will be set by *sequence 3*, but no reset pulse is generated during the period *sequence 3* since the comparator input is positive. Thus no reset pulse appears in *Fig. 18* (*k*). The small negative voltages appearing are insufficient to cause reset action.

Fig. 18 (*l*) showing the output voltage waveform of FF_3 illustrates how FF_3 is set by *sequence 3* and remains set for the remainder of the cycle until it is reset during the period *sequence 1*. Since FF_3 remains set, a readout pulse corresponding to FF_3 appears in *Fig. 18* (*n*).

An illustration of the conversion of an input which varies between the two positive levels of approximately one and three volts is shown in *Fig. 19*. The input is varying at a 1 kilocycle per second rate. For clarity of the illustration, a clock rate of 32 *kc* was chosen. It is desirable that the clock and input signals be synchronized.

Waveform (*a*) in *Fig. 19* is the *sequence 1* pulse to give a time reference. *Fig. 19* (*b*) illustrates the output obtained for full scale input voltage.

The binary word description of the input waveform is given by *Fig. 19* (*c*) and the input waveform is displayed by waveform (*d*).

Fig. 20 shows the output pulse obtained for a given *d-c* input voltage as the clock pulse rate was changed from 10 *kc* to 300 *kc*. *Sequence 1* pulse is also shown for reference. While some degradation of the output pulse occurs as the clock rate is increased, the wave-

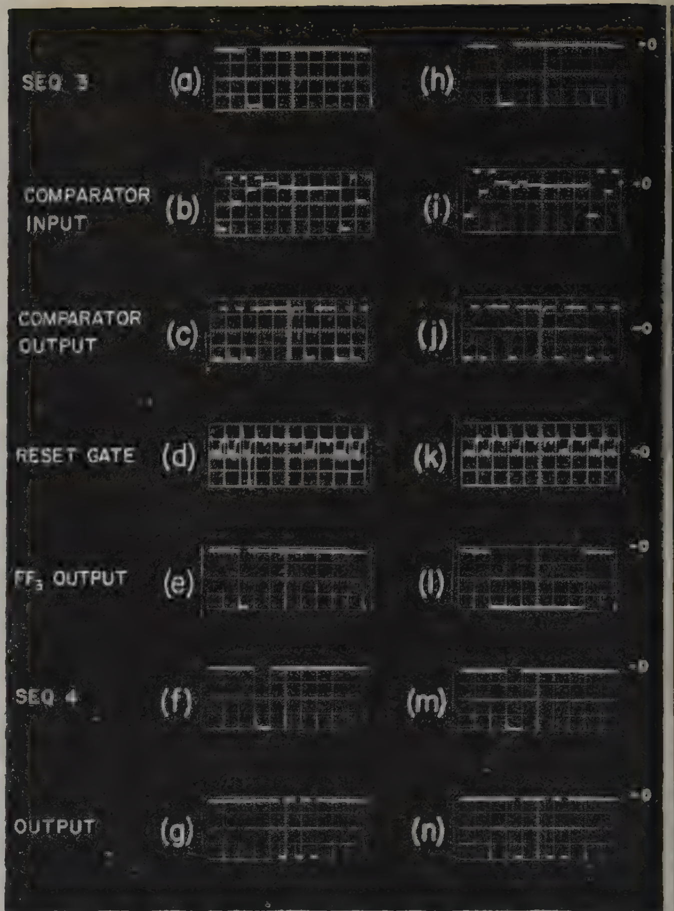

Fig. 18—Operating voltage waveforms.

form obtained with a clock rate of 300 *kc* is quite acceptable. Operation at clock rates in excess of 350 *kc* gave somewhat erratic results.

The transfer plot of the analog to digital converter was obtained for clock frequencies from 10 *kc* to 300 *kc*. No appreciable calibration shift was noted as the clock rate was altered. The largest percentage of full scale error for the decision points was 0.65 percent.

The highest absolute error for voltages which were multiples of 40 millivolts was slightly greater than one percent from 400 millivolts up. These accuracy figures are quite acceptable because the accuracy of the precision resistors in the prototype model was one percent.

The use of reference resistors with a tighter tolerance might reduce the error slightly although the maximum possible error of a seven-decision system is slightly less than 0.4 percent of full scale. This would allow a maximum absolute error of 4 percent at 500 millivolts if we assume that the entire error rests in the decision making.

Certainly the accuracy of the converter is dependent upon the regulation of the power supplies. The two 15-volts supplies should be regulated within ±1 volt or better. Current drain on the negative supply is slightly greater than 100 *ma* while the drain on the positive supply is only 25 *ma*.

The 128-volt reference supply must be well regulated as any error in this supply voltage will be present in the output. For optimum accuracy, this supply voltage should be made equal to 128.7 volts to

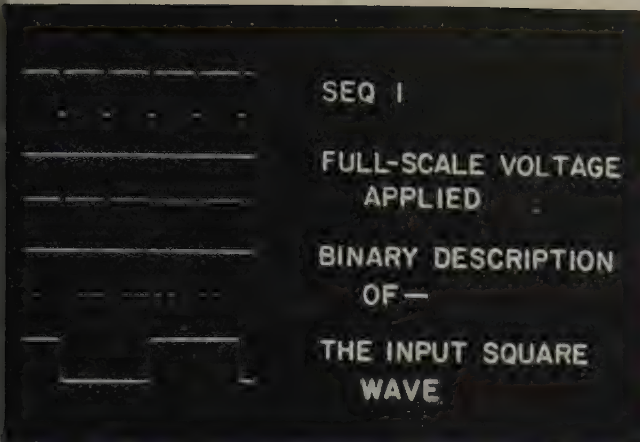

Fig. 19—Binary description of a square wave.

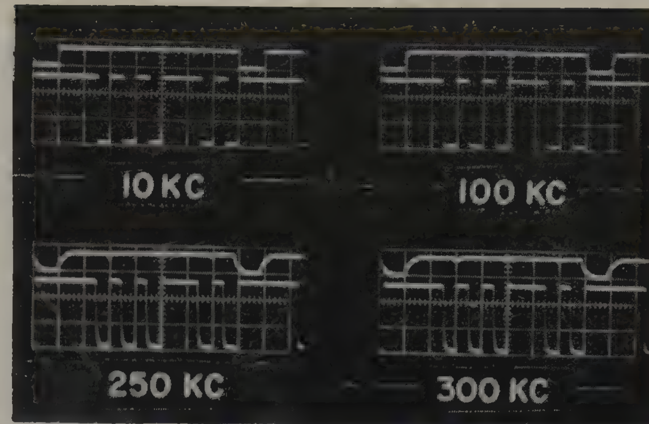

Fig. 20—Output vs. frequency.

llow for the small drop across the series diodes in he binary to analog converter.

cknowledgment

The many suggestions contributed by W. Steiger and M. Morishita were most helpful and are gratefully acknowledged. Mr. Morishita also constructed the prototype model and conducted the required tests necessary for the completion of the design.

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Electrically Variable Time Delay Using Cascaded Drift Transistors

R. W. AHRONS*

The function of electrically variable time delay can be performed by varying the collector bias voltage and current of a transistor with a drift field in the base region. However the cut-off frequency of the transistor also varies. The measuring factor, $f_{co}T$, cut-off frequency times delay, is a function of the device. The drift transistor has twice the $f_{co}T$ per single stage as an *R-C* circuit where the capacitance, *C*, is electrically variable. With cascaded stages a net gain in $f_{co}T$ of the cascaded unit is obtained. This net gain is tabulated as a function of number of stages. As an example, eight cascaded 2N384 transistors provide variation of delay of .11 μsec with a minimum cut-off frequency of 5 *mc*.

MANY ELECTRONIC SYSTEMS require a device in which a signal is delayed in time; the amount of this delay is controlled by another electrical signal. Transistors containing drift fields perform such a delay function when the voltage bias on the collector junction is varied. The cut-off frequency is decreased as the delay is increased. However, the product of delay and cut-off frequency is a function only of the type of transistor. This product can be increased by cascading a number of transistor stages. As an example, a circuit comprising eight 2N384 transistors provides a variation of delay of 0.11 μsec with a minimum cut-off frequency of 5 *mc*. In most practical cases there is a number of stages at which a maximum product of minimum cut-off frequency and variation of delay is obtained. This number of stages

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is a function of the ratio of the maximum alpha cut-off frequency of the transistor and minimum cut-off frequency specified in the circuit design. This article compares the product of cut-off frequency and delay for single units of various types of transistors and a variable capacitor. Furthermore, the increase in this product when cascading is tabulated as a function of the number of stages.

It was recognized by Bedford and Fredendall in 1939[1] that cascade *R-C* stages give an effective delay. The cut-off frequency (3 *db* point) of cascaded *R-C* circuits decreases approximately with the number of stages to the 1/2 power. However, the delay through each stage adds linearly. Thus, in cascading, the delay increases more rapidly than the cut-off frequency decreases. If electrically variable capacitors such as *p-n* junction devices are used in an *R-C* circuit, a variation of delay can be obtained. There is also a variation in frequency response.

In a triode transistor device the minority carriers traverse the base region in a finite transit time. This transit time may be varied electrically by altering the field inside the base region or by changing the electrical width of that region. The latter may be accomplished by changing the width of the collector depletion layer as a function of collector voltage (the "Early Effect"). However, in the case of transistors, the change in transit time or delay is also accompanied by an inverse change in cut-off frequency. As in the case of cascading *R-C* stages, the delay increases more rapidly than the cut-off frequency decreases. Since the advantage of cascading is the same for all devices, the complete circuit can be evaluated by the product of the transit time and the cut-off frequency for each stage. For *R-C* stages and several types of transistors, this product, $f_{co}\tau$, is shown in Table 1. Appendix A contains the derivation of $f_{co}\tau$ for each circuit or device.

The exponential or *erf* graded base has the highest product among the transistors with different base grading. Fortunately, in the drift transistor the grading in the base region closely resembles an *erf* function. Except for the case of a transistor with an external drift field imposed in the base, $f_{co}\tau$ is independent of electrical parameters. In this latter case the $f_{co}\tau$ product is a function of the internal base voltage from collector to emitter. The use of an external drift field appears to show good promise, but a practical device with this drift field is presently difficult to fabricate.

If several of one of the above types of devices are cascaded, the composite product of delay and frequency cut-off is:

$$f_o d = n\sqrt{2^{1/n}-1}\, f_{co}\,\tau \tag{1}$$

where $f_{co}\tau$ is the product of delay, τ, and cut-off frequency f_{co}, associated with the single stage and n is the number of stages. The derivation of Eq. 1 appears in Appendix B. Table 2 shows the values of

$$\sqrt{2^{1/n}-1},\ n\sqrt{2^{1/n}-1} \text{ and } \frac{n\sqrt{2^{1/n}-1}}{2\pi}\ vs\ n.$$

For example, with the use of eight cascaded transistors, one obtains a factor of 2.4 increase over that of the single stage case.

In most practical cases, there is a minimum delay associated with each stage. The amount of variable delay, Δd, is given by the difference between maximum and minimum delay. Hence,

$$f_o\,\Delta d = n\sqrt{2^{1/n}-1}\, f_{co}\left(1-\frac{f_o}{f_{co\,\max}\sqrt{2^{1/n}-1}}\right) \tag{2}$$

Furthermore, for a given minimum cut-off frequency f_o, specified in the circuit design, there is an optimum number of stages at which the $f_o\,\Delta d$ is a maximum. This maximum occurs when

$$n_{\text{opt}} = .69\left(1/2\,\frac{f_{co\,\max}}{f_o}\right) \tag{3}$$

Eq. 2 and 3 are derived in Appendix C. Thus, for a fixed minimum frequency, f_o, the amount of variation in delay will decrease beyond n_{opt} of Eq. 3.

Table 1—$f_{co}\tau$ for Various Single Stages

Circuit or Device	$f_{co}\tau$
R-C	$\frac{1}{2\pi}$
Uniformly Graded Base Transistor	$\frac{1}{2\pi}$
Linearly Graded Base Transistor	$\frac{\sqrt{2}}{2\pi}$
Exponentially or "erf" Graded Base Transistors	$\approx\frac{2}{2\pi}$
External Drift Field in Base Transistor	$\frac{4.4}{2\pi}V^{1/2}$

Table 2—Numbers Used in Cascading *n* Stages

n	$\sqrt{2^{1/n}-1}$	$n\sqrt{2^{1/n}-1}$	$\frac{n\sqrt{2^{1/n}-1}}{2\pi}$
1	1.000	1.00	0.159
2	0.643	1.29	0.205
3	0.509	1.53	0.244
4	0.436	1.74	0.277
5	0.384	1.92	0.304
6	0.349	2.09	0.332
7	0.322	2.25	0.358
8	0.302	2.40	0.382
9	0.282	2.54	0.404
10	0.268	2.68	0.426
12	0.243	2.92	0.465
16	0.216	3.36	0.535
20	0.187	3.74	0.595
24	0.171	4.10	0.652
32	0.148	4.74	0.755

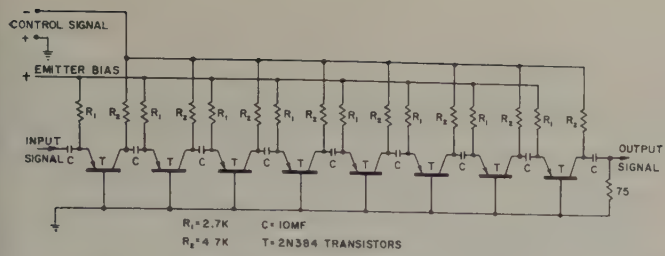

Fig. 1—Transistor variable delay circuit.

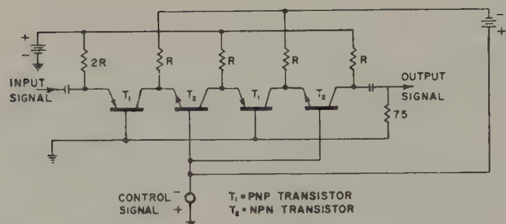

Fig. 2—Transistor variable delay circuit with complementary symmetry.

Results

Eight 2N247 and 2N384 transistors were tested in the cascade circuit shown in *Fig. 1*. Table 3 shows the measured and calculated (from Eq. 1 and Table 1) results.

Table 3—Measurement and Calculation of Delay

Transistors	$f_{o\,min}$ mc	Measured Delay (μ sec) Max-Min	Calculated Delay (μ sec) Max-Min	Collector Voltage Max volts	Min volts
(8) 2N384	5	.15-.04	.158-.026	6.4	.42
(8) 2N247	5	.16-.08	.158-.088	10.5	2.0

The 2N384 is listed as having a 100 *mc* alpha (grounded-base) cut-off frequency; the 2N247, 30 *mc*.[2]

The measurements and calculations agree to within reasonable limits. It should be noted that one major advantage of the circuit of *Fig. 1* is that the gain of each stage is approximately unity and varies only a few percent within the life of the transistor.

In the circuit of *Fig. 1*, the control signal tends to mix with the delayed signal. If the frequency spectrum of the control signal and the delayed signal do not overlap, the capacitors, *C*, can filter the control signal from the delayed signal. However, if these two signals do overlap and if it is not desirable to remove this control signal by subtraction means, the cascade transistor circuit configuration of *Fig. 2* offers a solution. This circuit contains alternate *npn* and *pnp* transistors. The control signal does not appear in the delayed signal.

APPENDIX A

Derivation of the Product, $f_{co}\tau$

The product, $f_{co}\,\tau$, for a single stage or device is derived for the following five cases.

Case 1 *R-C* Circuit

The phase angle of an *R-C* circuit such as that shown in *Fig. 3* is given by:

$$\phi = \tan^{-1}\frac{f}{f_{co}}$$

If ϕ is small, then $\phi \approx \dfrac{f}{f_{co}}$

Delay, $\tau = \dfrac{d\phi}{d\omega}$

Thus,

$$f_{co}\,\tau = \frac{1}{2\pi} \tag{A-1}$$

Case 2 Uniformly Graded Base Transistor

In the case of a triode transistor, the cut-off frequency is given by:

$$f_{co} = \frac{1}{\pi\sqrt{D}}\quad\frac{w}{(2\tau)^{3/2}} \tag{A-2}$$[3]

or

$$f_{co}\,\tau = \frac{1}{2\pi\sqrt{D}}\;\frac{w}{(2\tau)^{1/2}} \tag{A-3}$$

where *D* is the diffusion constant, τ is the transit time, and *w* is the width of the base region.

For the uniformly graded base:

$$\tau = \frac{w^2}{2D} \tag{A-4}$$[4]

Thus, from Eq. A-3:

$$f_{co}\,\tau = \frac{1}{2\pi} \tag{A-5}$$

Case 3 Linearly Graded Base Transistor

For the linearly graded base:

$$\tau = \frac{w^2}{4D} \tag{A-6}$$[5]

Thus, from Eq. A-3:

$$f_{co}\,\tau = \frac{\sqrt{2}}{2\pi} \tag{A-7}$$

Case 4 Exponentially Graded Base Transistor and Erf. Graded Base Transistor

The equation for τ for case 4 is complex and τ is a

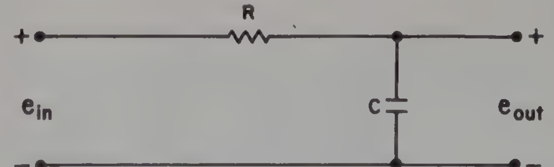

Fig. 3—R-C circuit.

function of relative impurity content at the boundaries of the base region. However τ/τ_o varies from 1/3 to 1/6 over three orders of relative impurity content.[6] $\tau_o = w^2/2D$. The results from *erf* or exponential functions are so clear that for all practical applications, this treatment will consider these two functions together. Thus,

$$f_{co}\,\tau = \frac{\sqrt{3} \text{ to } \sqrt{6}}{2\pi} \approx \frac{2}{2\pi} \qquad \text{(A-8)}$$

Case 5 External Drift Field in Base Transistor

An external voltage, V, which creates a drift field, E, in the base of a transistor, can control the transit time, τ, of the carriers which cross the base of width, w, such that:

$$\tau = \frac{w}{v} = \frac{w}{\mu E} = \frac{w^2}{\mu V} \qquad \text{(A-9)}$$

where v is the velocity of the minority carrier, μ is its mobility, and V is the drift voltage between emission and collection points. Using Eq. A-3,

$$f_{co}\,\tau = \frac{1}{2\pi\sqrt{D}}\,\frac{\sqrt{\mu V}}{\sqrt{2}} \qquad \text{(A-10)}$$

At a temperature of 300°K

$$f_{co}\,\tau = \frac{4.4}{2\pi}\,V^{1/2} \qquad \text{(A-11)}$$

APPENDIX B

Derivation of Cascading Equations

Consider a transfer function, h, of each stage as

$$h = \frac{1}{\sqrt{1+\left(\frac{f}{f_{co}}\right)^2}}\,e^{i\phi} \qquad \text{(B-1)}$$

Eq. B-1 is a good approximation for the transistor as well as the R-C circuit.[7] For n stages cascaded,

$$h_n = (h)^n = \left(\frac{1}{\sqrt{1+\left(\frac{f}{f_{co}}\right)^2}}\right)^n e^{in\phi} \qquad \text{(B-2)}$$

The delay,

$$d = \frac{dn\phi}{d\omega} = \frac{nd\phi}{d\omega} = n\tau \qquad \text{(B-3)}$$

The cut-off frequency, f_o, is the frequency f at which

$$|h_n| = \left(\frac{1}{\sqrt{1+\left(\frac{f_o}{f_{co}}\right)^2}}\right)^n = \frac{1}{\sqrt{2}} \qquad \text{(B-4)}$$

Thus,

$$f_o = \sqrt{2^{1/n}-1}\,f_{co} \qquad \text{(B-5)}$$

and finally,

$$f_o\,d = n\sqrt{2^{1/n}-1}\,f_{co}\,\tau \qquad \text{(B-6)}$$

Eq. B-6 is Eq. 1 in the text.

APPENDIX C

Derivation of Optimum Number of Stages

Since all practical devices have a minimum delay, there is an optimum number of stages, n_{opt}, at which the variable delay, Δd, is maximized. This maximum is a function of minimum cut-off frequency f_o.

$$\Delta d = d - d_{\min} = n\sqrt{2^{1/n}-1}\,f_{co}\,\tau\left(\frac{1}{f_o} - \frac{1}{f_{o\ \max}}\right) \qquad \text{(C-1)}$$

From Eq. B-5

$$f_{o\ \max} = f_{co\ \max}\sqrt{2^{1/n}-1}$$

Thus,

$$f_o\,\Delta d = n\sqrt{2^{1/n}-1}\,f_{co}\,\tau\left(1 - \frac{f_o}{f_{co\ \max}\sqrt{2^{1/n}-1}}\right) \qquad \text{(C-2)}$$

Eq. C-2 is Eq. 2 in the text.

$$2^{1/n} = 1 + \frac{1}{n}\log 2 + \frac{1}{2n^2}(\log 2)^2 + \ldots.$$

Using only the first two terms of the series as an approximation, if

$$\sqrt{2^{1/n}-1} = n^{1/2}(\log 2)^{1/2} = .83n^{1/2} \qquad \text{(C-3)}$$

Then,

$$f_o\Delta d = f_{co}\,\tau\left(.83n^{1/2} - n\,\frac{f_o}{f_{co\ \max}}\right) \qquad \text{(C-4)}$$

For a maximum,

$$\frac{d(f_o\Delta d)}{dn} = f_{co}\,\tau\left(\frac{.83}{2}\,n^{-1/2} - \frac{f_o}{f_{co\ \max}}\right) = 0 \qquad \text{(C-5)}$$

Then,

$$n_{\text{opt}} = .69\left(\frac{1}{2}\,\frac{f_{co\ \max}}{f_o}\right)^2 \qquad \text{(C-6)}$$

Eq. C-6 is Eq. 3 of text.

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Electrical Representation of the Drift Transistor

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Since the drift transistor is an electronic device, it is desirable to find an electrical analogue for drift transistor action. The analogue found is a distributed electrical system or transmission line. The analogue is developed in general form such that, for zero drift field, it becomes the well known diffusion transistor analogue. All electrical parameters are expressed in terms of physical parameters. The capacitance and resistance distributions are functions only of the impurity distribution, so that any arbitrary impurity distribution can be simulated by means of the corresponding resistance and capacitance functions. As a specific example, for an exponential impurity distribution in the base layer of the transistor the capacitance and resistance per unit length respectively increase and decrease exponentially. The current and minority carrier distributions and the four-pole parameters are calculated from the electrical analogue for the exponential distribution. The emitter and collector diffusion capacitances and the stored charge are also calculated. The parameters as calculated from the electrical analogue are in agreement with published results calculated from the physical system. This shows that the analogue described is the natural electrical analogue for the drift transistor.

Introduction

The exact electrical analogue for uniform-base junction transistors is well known.[1,2,3] We now wish to extend this analogue to drift transistors, with the diffusion transistor included as the limiting case for zero drift field. The analogy will be developed in general form. Various parameters will be calculated for the case of an exponential impurity distribution.

We will calculate the parameters for the intrinsic transistor. The overall parameters may be determined by adding the emitter and collector transition capacitances at the boundaries, and by adding the base impedance in series with the base lead. The emitter efficiency may be represented by an impedance at the emitter boundary. (*Fig. 8*)

The minority carrier distribution in the base region leads to an equivalent distributed capacitance which will be called the "diffusion capacitance" function. The definite integral of this function will be called the "total internal capacitance." Fractions of this capacitance will appear at the emitter and collector, and will be called respectively "emitter diffusion capacitance" and "collector diffusion capacitance."

For an exponential impurity distribution, at small injection levels, we have the case of constant "built-in" field at the base layer. However, for high injection levels the field should be modified and the general equations will utilize a current dependent field.

Continuity Equation for the Minority Carrier Flow

The minority carrier concentration in the base region is a function of time and distance. We may consider an infinitesimal volume element of area A, and length dx. The continuity equation for this volume is:

$$qA\,\frac{\delta N}{\delta t} = -\frac{qA}{\tau}\,(N - N_0) - \frac{\delta i}{\delta x} \tag{1}$$

where N = average minority carrier concentration within the volume element,
N_0 = thermal equilibrium concentration,
q = electronic charge,
τ = mean lifetime of the minority carriers,
i = minority carrier current.

We will now define a quantity, charge per unit length:

$$Q^* = qA\,(N - N_0) \tag{2}$$

(The asterisk will hereafter be used to denote quantities for unit length.) Rewriting Equation (1) and utilizing Equation (2), we obtain:

$$\frac{\delta Q^*}{\delta t} = -\frac{1}{\tau}\,Q^* - \frac{\delta i}{\delta x} \tag{3}$$

The minority current with an aiding field is the sum of the diffusion and drift currents, thus:

$$i = -qAD\,\frac{dN}{dx} + qA\,\mu\,E_b\,N$$

If the electric field in the base region is current independent, (the case for a built in field at sufficiently small current densities in a drift transistor), the terms in the above equation may be added.

For most practical cases $N_0 \ll N$, and we may write:

$$i = -D\,\frac{dQ^*}{dx} + \mu E_b\,Q^* \tag{4}$$

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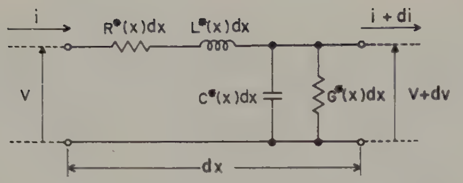

Fig. 1—General non-uniform transmission line section.

where D = diffusion constant of the minority carriers,
μ = mobility of the minority carriers,
E_b = "built-in" electric field.

Continuity Equation for the Electrical System

Let us consider a system consisting of an infinite chain of networks such as shown in *Fig. 1*.
The network component $R^*(x)$ [Ω/cm], $L^*(x)$ [Hy/cm], $C^*(x)$ [F/cm], $G^*(x)$ [$1/\Omega$ cm], are functions of x.

Because the charge is conserved, we may write, for the element of length dx,

$$\frac{\delta Q^*}{\delta t}\,dx = -Q^*\,\frac{G^*}{C^*}\,dx - di$$

or

$$\frac{\delta Q^*}{\delta t} = -Q^*\,\frac{G^*}{C^*} - \frac{\delta i}{\delta x} \tag{5}$$

where Q^* is now seen to be the charge on C^*.

The analogy to Equation (3) is immediately apparent. The voltage drop in *Fig. 1* may be written as:

$$-dV = i\,R^*\,dx + L^*\,dx\,\frac{di}{dt} \tag{6}$$

Equation (6) may also be written as:

$$-\frac{dV}{dx} = i\,R^* + L^*\,\frac{di}{dt} \tag{7}$$

Since di/dt is a second time derivative of the charge, and since there is no such term in the physical equations, (1) through (4), we have $L^* = 0$, and we need only consider the equivalent circuit of *Fig. 2*, instead of that of *Fig. 1*.
Equation (7) is now reduced to the simpler form:

$$i = -\frac{1}{R^*}\,\frac{dV}{dx} \tag{8}$$

Considering an infinitesimal dx section the voltage may be written as:

$$V = \frac{Q^*\,dx}{C^*\,dx} = \frac{Q^*}{C^*} \tag{9}$$

The voltage in Equation (8) may be replaced by the

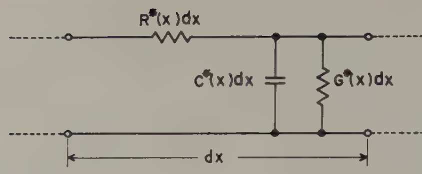

Fig. 2—Non-uniform RCG transmission line for transistor base region representation.

expression in Equation (9), to yield:

$$i = -\frac{1}{R^*\,C^*}\,\frac{dQ^*}{dx} + \frac{1}{R^*\,C^{*2}}\,\frac{dC^*}{dx}\,Q^* \tag{10}$$

which corresponds to Equation (4).

Correspondence of Parameters

From Equations (3), (4), (5), and (10), it follows that:

$$\tau(x) = \frac{C^*(x)}{G^*(x)} \tag{11}$$

$$D(x) = \frac{1}{R^*(x)\,C^*(x)} \tag{12}$$

$$\mu(x)\,E_b(x) = \frac{1}{R^*(x)\,C^*(x)}\,\frac{C^{*\prime}(x)}{C^*(x)} \tag{13}$$

These equations are general. Knowing the physical functions, we may obtain electrical ones. For example, the diffusion capacitance distribution is:

$$\frac{C^{*\prime}(x)}{C^*(x)} = \frac{\mu(x)\,E_b(x)}{D(x)} \tag{14}$$

After determining $C^*(x)$ in Equation (14), $R^*(x)$ and $G^*(x)$ can be determined from:

$$R^*(x) = \frac{1}{D(x)\,C^*(x)} \tag{15}$$

and

$$G^*(x) = \frac{C^*(x)}{\tau(x)} \tag{16}$$

Parameters Within a Finite Length

The general solutions in the previous section apply to an unbounded system. We shall now proceed to solutions for a finite system. In order to simplify the bounded system solutions, let us make some assumptions.

a. Kroemer[4] has shown that for an exponential impurity distribution the built-in electric field is constant. Let us use the quantity:

$$\eta = \frac{qE_b\,W}{kT} = \ln\left(\frac{\text{em. imp. conc.}}{\text{imp. conc. at W}}\right) \tag{17}$$

which is x independent.

b. μ and D are assumed to be x independent, and the Einstein relation to be true.

$$\frac{\mu}{D} = \frac{q}{kT} \tag{18}$$

With these assumptions, the diffusion capacitance distribution from Equation (14) becomes:

$$\frac{C^{*\prime}}{C^*} = \frac{q\,E_b}{kT} = \frac{\eta}{W} \tag{19}$$

and the solution is:

$$C^* = C_0^*\, e^{\eta \frac{x}{W}} \tag{20}$$

Since D is constant, R^* may be written as:

$$R^* = \frac{1}{DC^*} = \frac{1}{DC_0^*}\, e^{-\eta \frac{x}{W}} \tag{21}$$

Equations (20) and (21) contain the integration constant $C_0 = C^*\ (x = 0)$. The integral of R^* must be identified as the low frequency value of the input impedance, h_{11}, in order to match it to the transistor. (The value of this integration constant is not of importance for charge distribution considerations.) It is[5]:

$$\frac{kT}{qI_E} = \int_0^{x=W} R^*\, dx = \frac{1}{C_0^*}\,\frac{W}{D}\,\frac{1 - e^{-\eta}}{\eta} \tag{22}$$

or

$$C_0^* = \frac{W}{D}\,\frac{qI_E}{kT}\,\frac{1 - e^{-\eta}}{\eta} \tag{23}$$

The total internal capacitance is:

$$C_{Di} = \int_0^{x=W} C^*\, dx = C_0^*\, W\, \frac{e^{\eta} - 1}{\eta}$$

$$C_{Di} = \frac{W^2}{D}\,\frac{qI_E}{kT}\,\frac{2}{\eta^2}\,(\cosh \eta - 1) \tag{24}$$

For $\eta = 0$, the case of the diffusion transistor is obtained, and in this special case:

$$C_{Di}\ (\text{diff}) = \frac{W^2}{D}\,\frac{qI_E}{kT} \tag{25}$$

and

$$C^*\ (\text{diff}) = \frac{W}{D}\,\frac{qI_E}{kT} \tag{26}$$

The functions $C^*\ (x, \eta)$ and $R^*\ (x, \eta)$ are plotted in *Figs. 3* and *4*. In *Fig. 3*, the ratio of C^* to C^* (diff) is the ordinate and Equations (20) and (26) have been used. In *Fig. 4*, the ratio R^* to kT/qI_EW is the ordinate. According to Eq. (15) and (26):

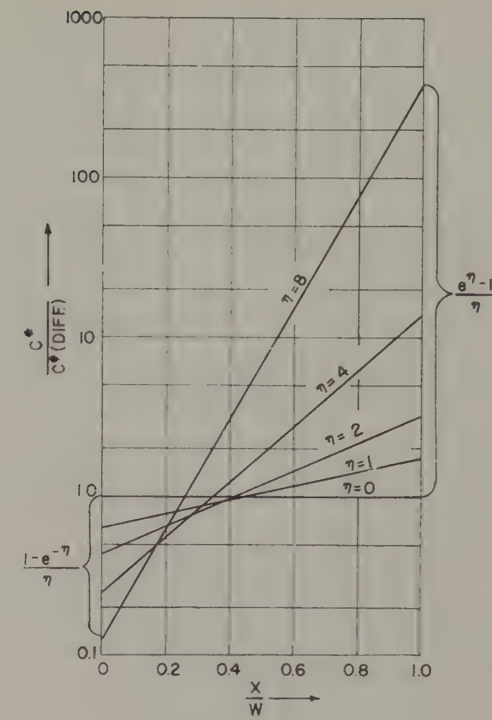

Fig. 3—Modification of the diffusion capacitance distribution by constant drift fields.

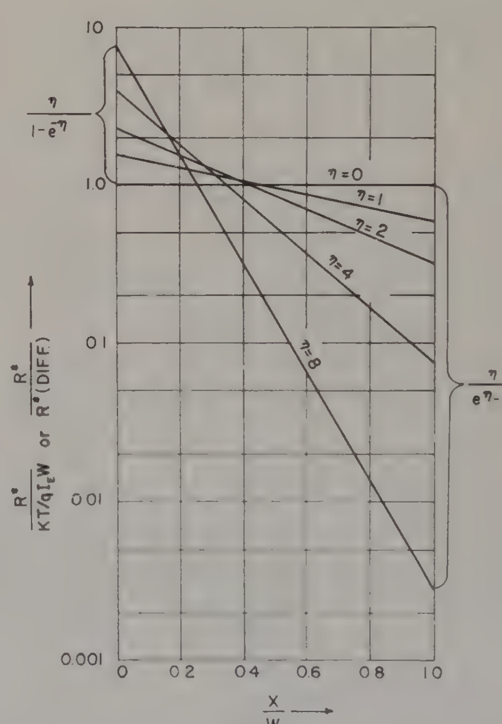

Fig. 4—Modification of the resistance distribution by constant drift fields.

$$\frac{R^* W\, qI_E}{kT} = \frac{W}{D}\,\frac{C^*\, qI_E}{kT} = \frac{C^*\ (\text{diff})}{C^*} \tag{27}$$

which indicates that the ordinate of *Fig. 4* is the reciprocal of that of *Fig. 3*.

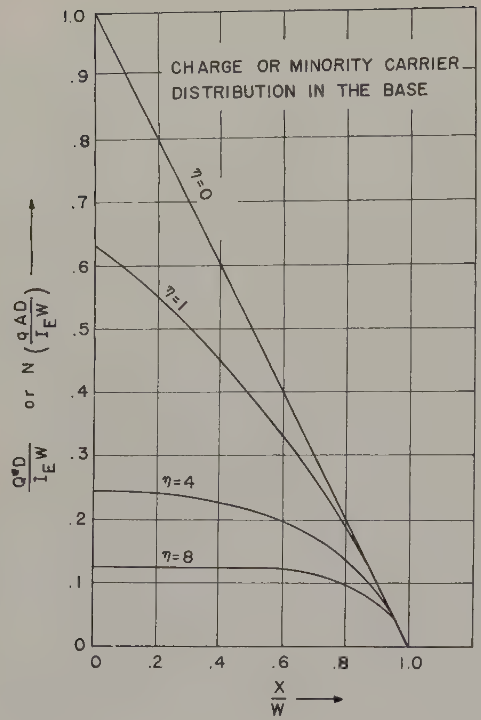

Fig. 5—Normalized charge distribution in the base region as obtained from the electrical analogue.

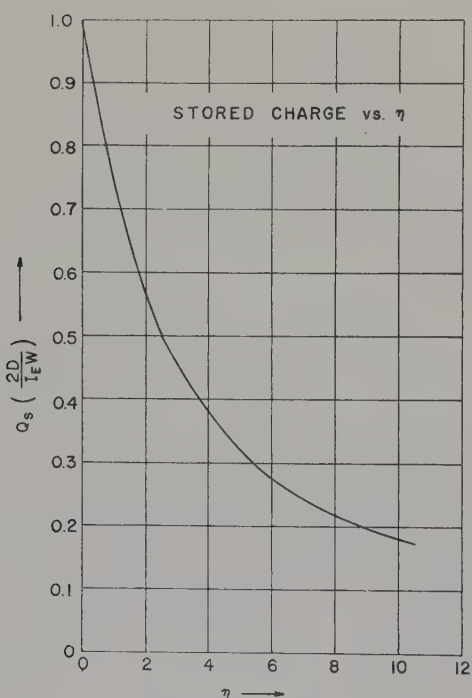

Fig. 6—Total stored charge in the base region as a function of the constant drift field.

If τ is constant, G^* may be obtained from Equation (16), as:

$$G^* = \frac{C^*(x)}{\tau} = \frac{C_0{}^*}{\tau}\, e^{\eta \frac{x}{W}} \tag{28}$$

Next we shall calculate the charge distribution,

$$Q^* = V\, C^* \tag{29}$$

in the base layer of the transistor. The voltage distribution $V(x)$ is obtained from Equation (8) as:

$$V = -I_E \int R^*\, dx = I_E \frac{W}{DC_0{}^*} \frac{e^{-\eta \frac{x}{W}}}{\eta} + \text{const.} \tag{30}$$

where Equation (21) has been used. It has been further assumed that volume recombination is so small as to be negligible, that displacement currents are absent ($\omega = 0$), and that injection efficiency is unity: then $i(x) = I_E$ is independent of x. The integration constant in Equation (30) is $-e^{-\eta}$, since the minority charge density at the boundary of the collector space charge layer vanishes, $Q^*(W) = 0$, and we have

$$Q^*(x) = I_E \frac{W}{D} \frac{1 - e^{\eta\left(\frac{x}{W} - 1\right)}}{\eta} \tag{31}$$

for the excess minority charge distribution in the base layer.

This equation indicates that the integration constant $C_0{}^*$ in Equation (20) is of no significance for the charge distribution.

The charge distribution of Equation (31) is plotted in *Fig.* 5. For $\eta = 0$ the factor in parenthesis becomes $\left(1 - \frac{x}{W}\right)$ which gives the excess minority charge distribution in the base of a diffusion transistor.

The total stored excess minority charge is:

$$Q_s = \int_0^{x=W} Q^*\, dx = I_E \frac{W^2}{D} \frac{\eta - 1 + e^{-\eta}}{\eta^2} \tag{32}$$

which is plotted in *Fig.* 6 as a function of η.

Voltage and Current Distributions

At high frequencies, the minority carrier current decreases throughout the base layer because of the shunt-admittance,

$$Y^* = G^* + j\omega C^*$$

of the equivalent network of *Fig.* 7.
Thus

$$-\frac{di}{dx} = Y^*\, V \tag{33}$$

and since

$$-\frac{dV}{dx} = i\, R^* \tag{34}$$

one obtains by elimination of $i(x)$:

$$\frac{d^2V}{dx^2} - \frac{1}{R^*}\frac{dR^*}{dx}\frac{dV}{dx} - R^*\, Y^*\, V = 0 \tag{35}$$

The quantity R^*Y^* is a simple function of the physical parameters of the transistor. According to Eq. (20), (21) and (28):

$$\bar{\gamma} = \sqrt{R^* Y^*} = \sqrt{\frac{1}{D\tau} + j\,\frac{\omega}{D}} = \text{const. with respect to } x. \tag{36}$$

Equation (35) can now be written:

$$\frac{d^2V}{dx^2} + \frac{\eta}{W}\frac{dV}{dx} - \bar{\gamma}^2 V = 0 \tag{37}$$

The general solution is:

$$V = A_1\, e^{\Gamma_1 x} + A_2\, e^{\Gamma_2 x} = V_{0+}\, e^{\Gamma_1 x} + V_{0-}\, e^{\Gamma_2 x} \tag{38}$$

which means there is a voltage wave traveling to the right, and a reflected one to the left.

Γ_1 and Γ_2 are the roots of the characteristic equation

$$\Gamma^2 + \frac{\eta}{W}\Gamma - \bar{\gamma}^2 = 0 \tag{39}$$

$$\Gamma_{1,2} = -\frac{\eta}{2W} \pm \sqrt{\left(\frac{\eta}{2W}\right)^2 + \bar{\gamma}^2} \tag{40}$$

We introduce, for later use:

$$W\Gamma_1,\; W\Gamma_2 = -\eta/2 \pm \sqrt{(\eta/2)^2 + (\bar{\gamma}\, W)^2} \tag{41}$$

The current distribution may be calculated from Equation (34), as

$$i = -\frac{qI_E}{kT}\,\frac{1 - e^{-\eta}}{\eta}\, e^{\eta \frac{x}{W}}\,(V_{0+}\, W\Gamma_1\, e^{\Gamma_1 x} + V_{0-}\, W\Gamma_2\, e^{\Gamma_2 x}) \tag{42}$$

For a finite length, we may write the voltages and currents at the boundaries of the base region as:

$$\text{at } x = 0 \begin{cases} V_1 = V_{0+} + V_{0-} & (43) \\ i_1 = -\dfrac{qI_E}{kT}\,\dfrac{1 - e^{-\eta}}{\eta}\,(V_{0+}\, W\Gamma_1 + V_{0-}\, W\Gamma_2) & (44) \end{cases}$$

$$\text{at } x = W \begin{cases} V_2 = V_{0+}\, e^{\Gamma_1 W} + V_{0-}\, e^{\Gamma_2 W} & (45) \\ i_2 = -\dfrac{qI_E}{kT}\,\dfrac{e^{\eta} - 1}{\eta} \\ \qquad (V_{0+}\, W\Gamma_1\, e^{W\Gamma_1} + V_{0-}\, W\Gamma_2\, e^{W\Gamma_2}) & (46) \end{cases}$$

In order to obtain the transistor behavior for small signals at high frequencies, the equivalent circuit in *Fig. 8* can be used.[6] In *Fig. 8*, the boxed-in part is the distributed network (intrinsic transistor) with an added voltage amplification, K_c, which accounts for the minority carrier current flow across the collecter space charge layer. The output voltage at the collector terminals is K_cV_2, where V_2 is given by Equation (45). K_c may be identified as[7]:

$$K_c = -\frac{q}{kT}\,\frac{dV_c}{dW}\, W\, \frac{e^{\eta} - 1}{\eta} \tag{47}$$

The equivalent circuit parameters outside of the boxed-in part have the following significance: C_e and C_c are the emitter and collector space charge layer capacitances; Y_d is the surface recombination admittance; Z_b is the impedance in the base layer in a direction perpendicular to the minority carrier flow between emitter and collector. The four-pole parameters will be calculated for the intrinsic transistor and the overall parameters may be calculated making use of C_e, C_c and Z_b.

Four-Pole Parameters of the Intrinsic Transistor

First we shall calculate the input admittance, y_{11}.

$$y_{11} = \left(\frac{i_1}{V_1}\right)_{V_2=0} = -\frac{qI_E}{kT}\,\frac{1 - e^{-\eta}}{\eta}\,\frac{W\Gamma_1 - W\Gamma_2\, e^{(\Gamma_1 - \Gamma_2)W}}{1 - e^{(\Gamma_1 - \Gamma_2)W}} \tag{48}$$

$$y_{11} = \frac{qI_E}{kT}\,\frac{1 - e^{-\eta}}{\eta}\,\left(\eta/2 + \sqrt{(\eta/2)^2 + (\bar{\gamma}W)^2}\,\coth\sqrt{(\eta/2)^2 + (\bar{\gamma}W)^2}\right)$$

where

$$(\bar{\gamma}W)^2 = \frac{W^2}{D\tau} + j\,\omega\,\frac{W^2}{D} \approx j\omega\,\frac{W^2}{D}$$

If we set $\eta = 0$, we obtain the diffusion transistor case:

$$y_{11}\,(\text{diff}) = \frac{qI_E}{kT}\,\bar{\gamma}W\,\coth\bar{\gamma}W \tag{49}$$

The forward transfer admittance, y_{21}, is:

$$y_{21} = -\left(\frac{i_2}{V_1}\right)_{V_2=0} = \frac{qI_E}{kT}\,\frac{e^{\eta} - 1}{\eta}\,\frac{W\Gamma_1\, e^{W\Gamma_1} - W\Gamma_2\, e^{W\Gamma_1}}{1 - e^{(\Gamma_1 - \Gamma_2)W}}$$

where the sign was changed, since we used outflowing

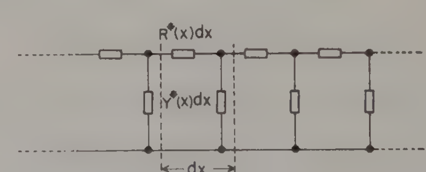

Fig. 7—The resistance-admittance network for calculation of voltage and current distributions in the base region.

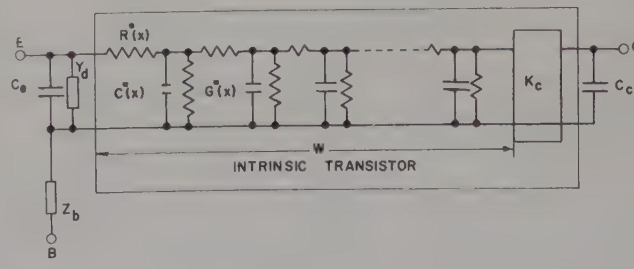

Fig. 8—Complete electrical representation of the transistor. Four-pole parameters are calculated only for the intrinsic transistor.

output current, whereas four-pole theory uses inflowing output current.

$$y_{21} = -\frac{qI_E}{kT}\frac{\sinh \eta/2}{\eta/2}\frac{\sqrt{(\eta/2)^2 + (\bar{\gamma}W)^2}}{\sinh \sqrt{(\eta/2)^2 + (\bar{\gamma}W)^2}} \quad (50)$$

For diffusion transistors, $\eta = 0$:

$$y_{21}\,(\text{diff}) = -\frac{qI_E}{kT}\frac{\bar{\gamma}W}{\sinh \bar{\gamma}W} \quad (51)$$

The reverse transfer admittance, y_{12}, is

$$y_{12} = \left(\frac{i_1}{K_c\, V_2}\right)_{V_1=0}$$

If the K_c amplification were not there, then $y_{12} = y_{21}$. However, in general $y_{12} = y_{21}/K_c$.

$$y_{12} = I_E\frac{1}{W}\frac{dW}{dV_c}e^{-\eta/2}\frac{\sqrt{(\eta/2)^2 + (\bar{\gamma}W)^2}}{\sinh \sqrt{(\eta/2)^2 + (\bar{\gamma}W)^2}} \quad (52)$$

For diffusion transistors, it reduces to

$$y_{12}\,(\text{diff}) = I_E\frac{dW}{dV_c}\frac{1}{W}\frac{\bar{\gamma}W}{\sinh \bar{\gamma}W} \quad (53)$$

The output admittance, y_{22}, is

$$y_{22} = -\left(\frac{i_2}{K_c\, V_2}\right)_{V_1=0} = -I_E\frac{dW}{dV_c}\frac{1}{W}\frac{W\Gamma_1 e^{W\Gamma_1} - W\Gamma_2 e^{W\Gamma_2}}{e^{W\Gamma_1} - e^{W\Gamma_2}} \quad (54)$$

$$y_{22} = -I_E\frac{dW}{dV_c}\frac{1}{W}\left(\sqrt{(\eta/2)^2 + (\bar{\gamma}W)^2}\coth\sqrt{(\eta/2)^2 + (\bar{\gamma}W)^2} - \eta/2\right)$$

For diffusion transistors

$$y_{22}\,(\text{diff}) = -I_E\frac{dW}{dV_c}\frac{1}{W}\bar{\gamma}W\coth\bar{\gamma}W \quad (55)$$

The transport factor, β, from Equations (44) and (46) is

$$\beta = \left(\frac{i_2}{i_1}\right)_{V_2=0} = e^{\eta}\frac{W\Gamma_1 e^{W\Gamma_1} - W\Gamma_2 e^{W\Gamma_1}}{W\Gamma_1 - W\Gamma_2 e^{(\Gamma_1 - \Gamma_2)W}}$$

or

$$\beta = \frac{e^{\eta/2}}{\cosh\sqrt{(\eta/2)^2 + (\bar{\gamma}W)^2} + \frac{\eta/2}{\sqrt{(\eta/2)^2 + (\bar{\gamma}W)^2}}\sinh\sqrt{(\eta/2)^2 + (\bar{\gamma}W)}} \quad (56)$$

For diffusion transistors,

$$\beta = \frac{1}{\cosh\bar{\gamma}W} \quad (57)$$

Emitter and Collector Diffusion Capacitance

The emitter diffusion capacitance, C_{De}, should be determined at low frequencies with shorted output. y_{11} may be called equivalent to a parallel R_p and C_{De} combination.

$$y_{11} \approx \frac{1}{R_p} + j\omega\, C_{De}$$

for high η, we obtain

$$C_{De} \approx \frac{W^2}{D}\frac{qI_E}{kT}\frac{1}{\eta^2} = C_{De}\,(\text{diff})\,\frac{3}{\eta^2} \quad (58)$$

The emitter diffusion capacitance for drift transistors is lower than the value for diffusion transistors, (with the same W), by the factor $3/\eta^2$.
For high η, only a fraction of the total internal diffusion capacitance appears at the emitter. Using Equations (24), and (58) we obtain

$$\frac{C_{De}}{C_{Di}} = e^{-\eta} \quad (59)$$

The collector diffusion capacitance, C_{Dc}, may be calculated in a similar manner.

$$y_{22} \approx \frac{1}{R_p} + j\omega\, C_{Dc}$$

For high η, we obtain

$$C_{Dc} \approx \frac{W^2}{D}\frac{qI_E}{KT}\frac{e^{\eta}}{\eta^2}\frac{1}{k_c} = -I_E\frac{dW}{dV_c}\frac{W}{D}\frac{1}{\eta} \quad (60)$$

and using equations (24) and (60), for high η

$$\frac{C_{Dc}}{C_{Di}} \approx \frac{1}{K_c} \quad (61)$$

This shows that, for high η, almost all of the diffusion capacitance is adjacent to the collector. At the same time most of the resistance is next to the emitter. Therefore, the external emitter status will not effect the value of C_{Dc}. Because of this, the internal diffusion capacitance will be transferred to the collector terminal with a factor of $1/K_c$.

Conclusions

The four-pole parameters, emitter and collector diffusion capacitances, derived by use of the electrical analogue presented here, are in agreement with those derived by Krömer.[8,9] The electrical equivalent circuit should be considered as the exact manner of describing the frequency behavior of the drift transistor. Equations (11) through (14) allow us to calculate the electrical equivalent for any impurity distribution. In general, as long as the built-in field is an aiding field, the capacitance function increases toward the

collector. When the diffusion constant is distance independent, the resistance function is the inverse of the capacitance function.

It is possible to construct a model of a drift transistor from a 15 or 20 Δx section approximation of the equivalent circuit. In this way the frequency behavior of an arbitrary impurity distribution can be measured.

Acknowledgement

The authors are grateful to Dr. K. Lehovec, R. Zuleeg, and K. Schoeni of this laboratory for advice and helpful discussion.

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Complementary Resistor Transistor Logic Circuits

S. C. CHAO*

Resistor transistor logic circuits using both types of junction transistors, including single level and multi-level *RTL* circuits are investigated. The complementary characteristic of these two types of *RTL* circuits are expressed in terms of Boolean algebra, which shows that one type is more suitable for handling *or-and* logic, while the other type is more suitable for *and-or* logic. The application of complementary and multi-level *RTL* circuits in large digital systems is emphasized because of its value in circuit simplification, component saving and improvement in reliability.

In this article, resistor transistor logic (*RTL*) circuits are discussed in a broad sense, including multi-level logic,[1] complementary circuitry and their interchangeability in terms of Boolean equations.[2,3] The value of using complementary and multi-level *RTL* circuits in a digital computer is illustrated by several typical logic expressions, which show simplification in circuitry, reduction in the number of transistors being used and potential improvement in over all reliability.

Cascade *RTL* circuits are also discussed briefly, and their rather stringent design problem as compared with that of parallel *RTL* circuits is pointed out.

Transistor logic using single input inverters is not treated since it has been dealt with in various books and articles.

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The stability and tolerance margin of multi-level *RTL* circuits has been discussed in a previous paper,[1] and shall not be repeated here.

Generalized *RTL* Circuits

First, let us define +V volts to represent binary '1', and —V volts as binary '0',* and

${}_nX_m$ = when m out of n inputs are '1', the output X is '0'.

${}_nY_m$ = when m out of n inputs are '0, the output Y is '1'.

Figs. 1(a) and *1(b)* are the basic *RTL* circuits, with one as the logic complement of the other. The bias current $(V_B - V)/R_B$ can be designed between any adjacent multiples of $2V/R$ such that when m out of n inputs are primed, '1's in *Fig. 1(a)* and '0's in *Fig. 1(b)*, the corresponding transistor is turned on and

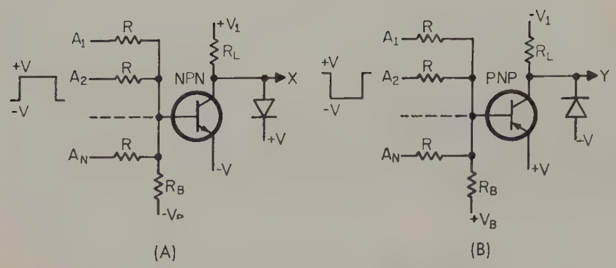


Fig. 1—Complementary RTL circuits.

its collector shows an output signal.[1] The clamping diodes at the collectors are for the purpose of improving the turn off delay, and stabilizing the 'off' levels so that they are not effected by loading, within the design limit, and temperature variation of I_{co}. Circuits with unclamped collectors have been used in *nor* circuit applications by properly designing the fan-in and fan-out conditions.[4,5] In multi-level *RTL* circuits, it is recommended that collector clamping be employed in order to improve marginal tolerance, in addition to increasing the circuit speed.

By definition,

$$_nX_1 = \overline{A_1 + A_2 \text{------} + A_n} = \overline{A}_1 \cdot \overline{A}_2 \cdots \overline{A}_n$$

$$_nX_2 = (A_1A_2 + A_2A_3 + \text{------}) = \Sigma\, (\overline{A}_1 \cdot \overline{A}_2 \cdots \overline{A}_{n-1}) \quad (1)$$

etc.

$$_nY_1 = \overline{A}_1 + \overline{A}_2 \text{---} + \overline{A}_n = \overline{A_1 \cdot A_2 \cdots A_n}$$

$$_nY_2 = \overline{A}_1 \cdot \overline{A}_2 + \overline{A}_2\overline{A}_3 + \cdots\cdots \quad (2)$$

etc.

It can be shown that $_nX_m = {}_nY_{n-m+1}$ (3)

For example, taking a 4-variable logic, i.e. $n = 4$, we have

$$_4X_1 = \overline{A_1+A_2+A_3+A_4} = \overline{A}_1 \cdot \overline{A}_2 \cdot \overline{A}_3 \cdot \overline{A}_4 = {}_4Y_4$$

$$_4X_2 = \overline{A_1A_2+A_1A_3+A_1A_4+A_2A_3+A_2A_4+A_3A_4}$$

$$= \overline{A}_1\overline{A}_2\overline{A}_3 + \overline{A}_1\overline{A}_2\overline{A}_4 + \overline{A}_1\overline{A}_3\overline{A}_4 + \overline{A}_2\overline{A}_3\overline{A}_4 = {}_4Y_3$$

$$_4X_3 = \overline{A_1A_2A_3 + A_1A_2A_4 + A_1A_3A_4 + A_2A_3A_4} \quad (4)$$

$$= \overline{A}_1\overline{A}_2 + \overline{A}_1\overline{A}_3 + \overline{A}_1\overline{A}_4 + \overline{A}_2\overline{A}_3 + \overline{A}_2\overline{A}_4 + \overline{A}_3\overline{A}_4 = {}_4Y_2$$

$$_4X_4 = \overline{A_1 \cdot A_2 \cdot A_3 \cdot A_4} = \overline{A}_1 + \overline{A}_2 + \overline{A}_3 + \overline{A}_4 = {}_4Y_1$$

* In practice, one of the signal levels may well be at ground potential, and all the voltage shift the same amount.

The above identities can be verified by Boolean algebra and DeMorgan's Theorem: "Any binary expression is equal to the negation of the expression obtained by changing all conjunctions to disjunctions and vice versa, and by replacing each variable with its negation." If we interchange the definition of true and false, i.e. '1' and '0', the positions of X and Y will be interchanged without any further change in these expressions.

Single Level RTL Circuits

By letting $m = 1$ in the previous equation, we have

$$_nX_1 = \overline{A_1 + A_2 + \text{-------} + A_n} \quad (\textit{or-not})$$
$$= \overline{A}_1 \cdot \overline{A}_2 \text{---} \overline{A}_n \quad (\textit{not-and}, \text{ or } \textit{nand}) \quad (1')$$

$$_nY_1 = \overline{A}_1 + \overline{A}_2 \text{----} + \overline{A}_n \quad (\textit{not-or}, \text{ or } \textit{nor})$$
$$= \overline{A_1 \cdot A_2 \cdots A_n} \quad (\textit{and-not}) \quad (2')$$

The complementary nature of these circuits is clearly seen from the above two equations (1′) and (2′). Although only one type of *RTL* circuit is sufficient to handle all kinds of complicated logic expressions, it is apparent that by employing both *nor* and *nand* circuits, a certain amount of simplification and component saving can be achieved because of the complementary characteristic of these circuits.

In general, the *nand* circuit is more suitable for *or-and* type logic, while the *nor* circuit is more suitable for *and-or* type logic. To illustrate the first part of this statement, take a 4-variable expression $(A + B)(C + D)$, which can be constructed by using three $_2X_1$ circuit blocks as shown in *Fig. 2 (a)*. However, if $_2Y_1$ circuit blocks are used, it requires five more inverters to accomplish the same goal, as shown in *Fig. 2 (b)*, unless the negations of these variables are all available, which saves four transistors. If $(A + B)(C + D)$ is converted to $AC + AD + BC + BD$ and the *nor* type circuits are used, a total of five transistors are required as shown in *Fig. 2 (c)*.

Another example, $AB + CD$, shall serve to support the second part of the statement, namely, that a *nor* circuit is preferred in this case. *Fig. 3 (a)* and *3 (b)* show the logic counterpart of *Fig. 2 (a)* and *2 (b)* respectively. If $AB + CD$ is converted to $(A + B)(A + D)(B + C)(B + D)$, a total of five *nand* circuits are required as shown in *Fig. 3 (c)*, which is the counterpart of *Fig. 2 (c)*.

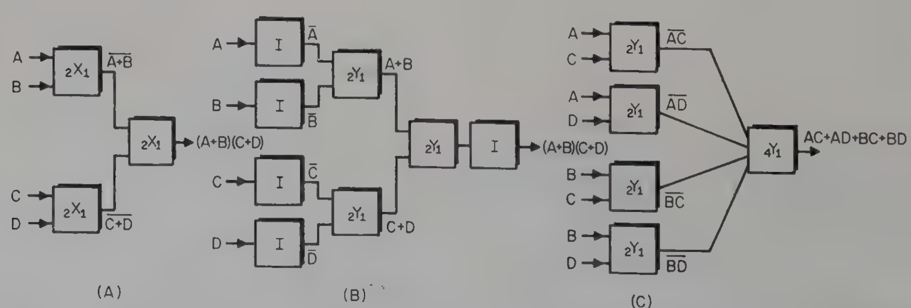


Fig. 2—Logic nets for (A + B) (C + D).

A general logic expression contains both *or* and *and* logic mixed in a rather complicated manner. Many times, it is not very straightforward to find the simplest equivalent expression which will require a minimum number of circuit blocks. However by mixing both *nor* and *nand* circuits as they fit, it is believed that the simplest and most economical result may be achieved.

This unique feature of an *RTL* circuit, for which there is no counterpart in tube circuits, has been applied in digital computers quite widely.[4,5] This is especially true due to the fact that the art of fabricating transistors has advanced considerably during the past years so that many types of transistors of better quality, higher operating speed and lower cost are now available commercially.

When comparing *RTL* with diode-amplifier logic circuits, the former has a comparable or faster circuit speed, and potentially lower overall cost because of its fewer components. Another advantage of using *RTL* is that the power dissipation distributes rather evenly in all parts of a machine so that temperature problems would be less severe. In diode logic, the driver amplifiers carry all the load current, and are more susceptible to temperature failures than the *RTL* circuits.

Multi-Level *RTL*

When the integer m is larger than one in Eq. (1) and (2), the circuits are called multi-level *RTL*. It was shown analytically how the tolerance of resistors and power supplies diminishes when the level, m, goes up.[1] Some three or four level circuits can be designed to work reliably with a combined resistor and voltage tolerance as high as ten per cent. This means that if the resistors are matched, or if 1% components are used, the voltage supplies may have as much as five per cent regulation without degenerating the circuit operation. Therefore, in a digital system, if a sizable number of transistors can be saved by using multi-level *RTL* circuits, and at the same time the tolerance or marginal requirement does not put a severe limitation on power supply by regulation, there appears to be no reason for not doing so.

Any multi-level *RTL* can be broken down into single level circuits as shown, e.g. in Eq. (1), (2) and (4), and hence it is not expected that they be considered as basic circuit blocks. In many instances, a fixed combination of logic occurs in numerous places in a digital computer; it is worthwhile to consider the use of multi-level circuits so that the number of transistors is reduced and the reliability increased. A few examples are given below to support this statement.

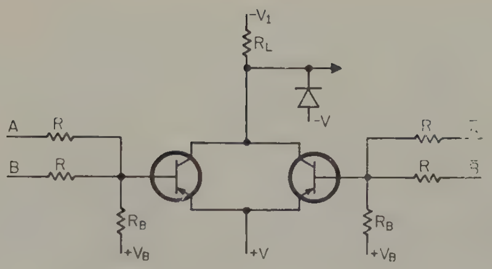


Fig. 4—Identity Comparator.

Illustrative Examples

1. Identity Comparator

The logic expression $AB + \overline{A}\ \overline{B}$ is true if the two variables A and B are the same, and is called an identity comparator. Suppose a digital system were required to compare, parallel by bits, two binary numbers each, say, thirty bits long. It would require thirty comparator circuits, and a total of ninety transistors would be required if single level *RTL* circuits are used. In *Fig. 4*, two ${}_2Y_2$ circuits with a common collector load resistor are used to perform the same function, resulting in a total saving of thirty transistors.

This circuit can be extended to handle more than two variables if higher level *RTL* circuits are used.

2. Full Comparator

A full comparator circuit is shown in *Fig. 5*, which uses the identity comparator and two *nor* circuits, ${}_2Y_2$, with one of the two inputs connected to the third collector to form a feedback loop. The logic expression is shown in Eq. (5), which explains clearly the definition of this circuit.

$$\begin{aligned} C_1 &= \overline{A} \cdot B \\ C_2 &= A \cdot \overline{B} \\ C_3 &= A \cdot B + \overline{A} \cdot \overline{B} \end{aligned} \tag{5}$$

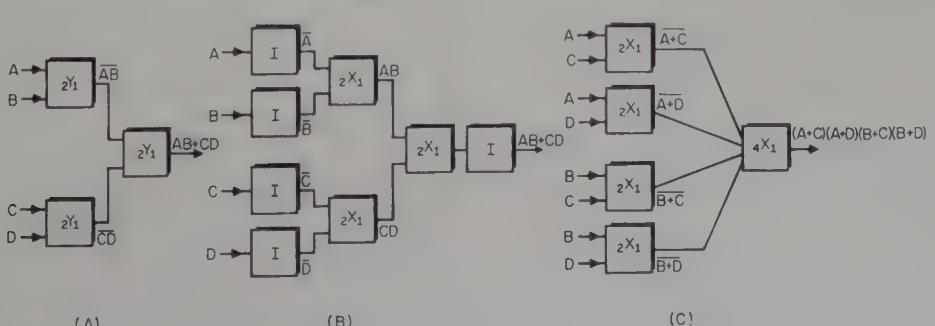


Fig. 3—Logic nets for AB + CD.

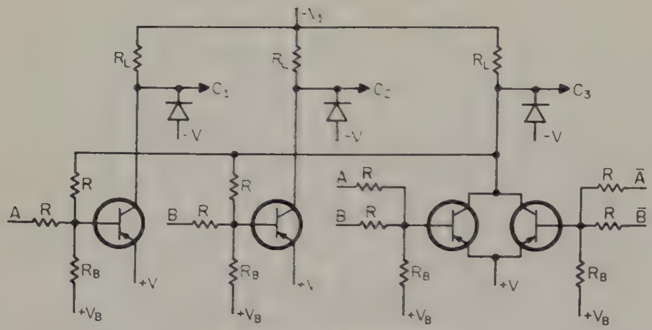
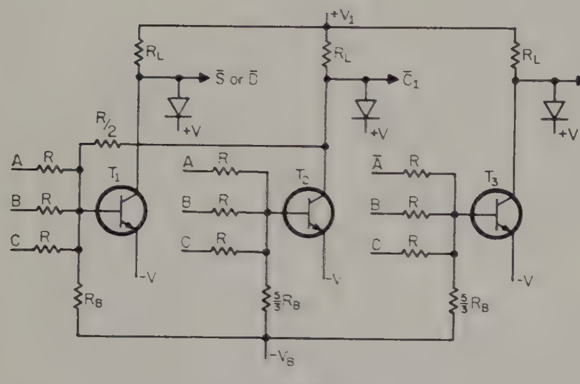
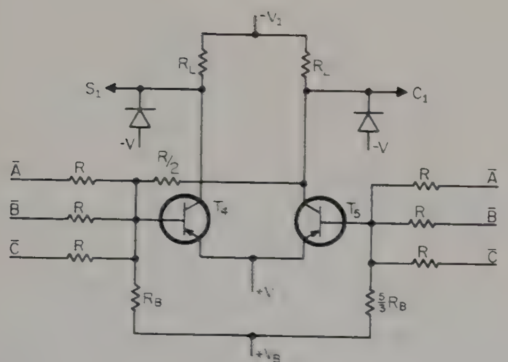


Fig. 5—Full Comparator.



(A)



(B)

Fig. 6—Binary Adder—Substractor.

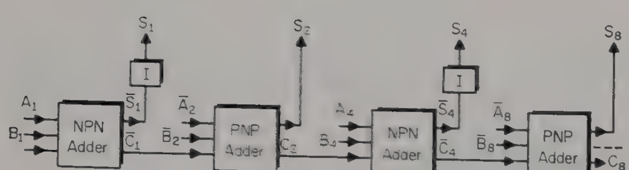


Fig. 7—Binary Parallel Adder.

This circuit finds applications in digital sorting and collating.

3. Binary Adder—Subtractor

From the truth table of three-input binary addition and subtraction, one sees that the sum, S, and different, D, are the same; only the carry, C_1 and the bollow, B_1, are different. The logic expressions are derived as given in Eq. (6).

			ADD		SUBT.	
A	B	C	S	C_1	D	B_1
0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	0	1	0	1	1
0	1	1	0	1	0	1
1	0	1	0	1	0	0
1	0	1	0	1	0	0
1	1	1	1	1	1	1

$$\begin{aligned} S &= D = A\cdot\bar{B}\cdot\bar{C} + \bar{A}\cdot B\cdot\bar{C} + \bar{A}\cdot\bar{B}\cdot C + A\cdot B\cdot C \\ C_1 &= A\cdot B + B\cdot C + C\cdot A \\ B_1 &= \bar{A}\cdot B + B\cdot C + C\cdot\bar{A} \end{aligned} \tag{6}$$

A two transistor full adder circuit was given in a reference paper[1], and it can be extended to handle subtraction by using a third transistor to take care of the bollow output, as shown in *Fig. 6(a)*, where T_2 and T_3 are two level circuits, ${}_3X_2$, while T_1 is a weighted four input circuit with a bias of $(V_B - V)/R_B \sim 5V/R$ and a feedback current from T_2 which equals $4V/R$ when T_2 is cut-off. This arrangement is derived from the logic expression $S = C_1\ (A+B+C) + ABC$ which is obtained from the first two expressions of Eq. (6). It should be noted that the outputs are actually $\bar{S}$, $\bar{C}_1$ and $\bar{B}_1$, which is the case for all *nand* circuits.

A complementary type full adder or subtractor can be derived by using *pnp* transistors, and it will satisfy logic expressions like Eq. (6) except that negations are used for each variable and vice versa, as shown in Eq. (7).

$$\begin{aligned} S_1 &= \bar{A}\cdot B\cdot C + A\cdot\bar{B}\cdot C + A\cdot B\cdot\bar{C} + \bar{A}\cdot\bar{B}\cdot\bar{C} \\ C_1 &= \bar{A}\cdot\bar{B} + \bar{B}\cdot\bar{C} + \bar{C}\cdot\bar{A} \end{aligned} \tag{7}$$

Fig. 6(b) shows a *pnp* type full adder. T_4 is biased such that $(V_B - V)/R_B \sim 5V/R$, and T_5 is a two level circuit ${}_3Y_2$.

When performing parallel addition of many binary bits, it is recommended that complementary types of adders be used for adjacent bits, assuming both true and false values of the input numbers are available as they may come from symmetrical flip-flop registers. Doing this will eliminate some phase inverting circuits. A typical 4-bit parallel adder using this arrangement is shown in *Fig. 7*.

4. Generating the Parity Bit and Parity Checking

The adder circuits described in Example 3 can be used to do parity checking, or to generate the parity bit. Assuming a seven bit code with odd parity, i.e., the 7th bit is decided such that the total number of '1's are odd. *Fig. 8* shows a circuit, with two *npn*

adders followed by a *pnp* adder, which may be used for both applications.

The 6-bit information is fed to the *npn* adders, three bits each as shown. The sum $\overline{S_1}$ or $\overline{S_2}$ is at $-V$ if the corresponding input group contains an odd number of '1's, and is at $+V$ if it contains an even number of '1's (zero is treated as an even number). The inputs to the third adder (*pnp*) are $\overline{S_1}$, $\overline{S_2}$ and a third input which is '0' when this setup is used for parity generation, and is $\overline{P}$ (the negation of the parity bit) when used for parity checking. When doing parity generation, if $\overline{S_1}$ and $\overline{S_2}$ are different, one of them is '0', T_4 (referring to *Fig. 6 b*), is cut-off because the third input is '0', and its output S_3 is at $-V$ which indicates a '0' for the parity bit. If $\overline{S_1}$ and $\overline{S_2}$ are identical, the total number of '1's is even, S_3 is at $+V$, which indicates a '1' for the parity bit. The reasoning is the same for parity checking; the parity is correct if S_3 is a '1', and incorrect if S_3 is a '0'.

The above examples illustrate a large reduction in the number of transistors used in each case in comparison with circuits using either single level *RTL* or diode-amplifier logic. To pay the price, these circuits require rather precise voltage sources and close tolerance resistors. These conditions can be met at a nominal cost.

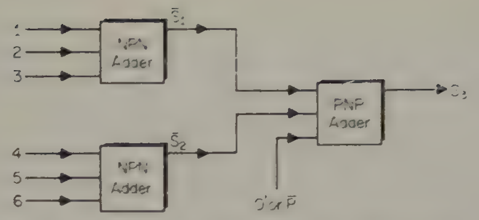


Fig. 8—Parity checking and generation.

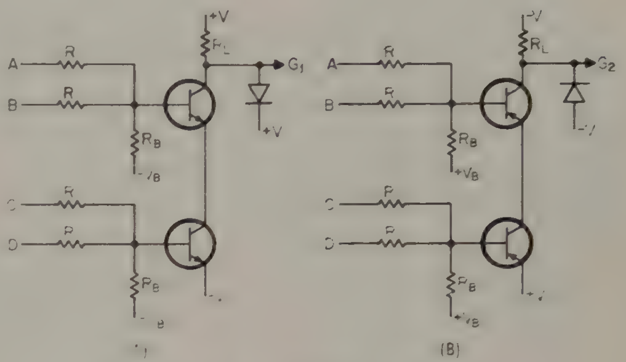


Fig. 9—Cascade RTL.

Cascade RTL Circuits

If transistors are cascaded serially with one load resistor at the end collector, and resistor logic is applied at the various base terminals, a cascade *RTL* circuit is formed. By doing this, a final stage *and* gate is eliminated, because all transistors must conduct in order to produce an output signal.

For example, considering single level *RTL*, *Fig. 9a* satisfies the logic expression $G_1 = \overline{(A+B)\,(C+D)} = \overline{A}\cdot\overline{B} + \overline{C}\cdot\overline{D}$ while *Fig. 9b* satisfies the logic expression $G_2 = (\overline{A} + \overline{B})\,(\overline{C} + \overline{D}) = \overline{A\cdot B + C\cdot D}$

Similar circuits can readily be constructed using cascade transistors for *and* gates. Also, it may be extended to deal with multi-level *RTL* circuits.

From the circuit design standpoint, cascade *RTL* requires more tightly controlled transistor parameters than those used in parallel *RTL* circuits. The saturation voltage drop across the transistor should be very low so that the total voltage drop in a series *and* gate shall not be excessive. The finite saturation voltage drop causes the current through the transistors to increase from the top to the bottom, while the reverse is true for the bias current. This inherently limits the number of transistors which can be cascaded without causing marginal operation or failure, unless each stage is designed differently to allow for adequate corrections.

Conclusion

Although complementary transistor circuitry has been known ever since the invention of this solid state device, circuit designers have not been able to take advantage of it very effectively because technical problems in fabricating well matched *npn* and *pnp* pairs. This is an even more important consideration in linear applications, such as push-pull amplifiers, than it is in switching applications. In the latter, such as in digital computers, it is not necessary to use matched pairs so long as each type of transistor satisfies a minimum specification, such as beta and alpha cutoff frequency.

Circuit design information of single level *nor* logic can be found in many previous papers; e.g., references (4), (5) and (6) of this article. In general, transistors suitable for *nor* circuitry should have low saturation voltage drop, low storage time, narrow spread to current gain (beta) and possibly short rise and fall time in order to minimize the propagation time between stages. Micro-alloy and diffused base type transistors are very suitable for *nor* circuit application. Philco MADT and Fairchild diffused base transistors are typical examples. *Nor* circuits employing these transistors work satisfactorily at a clock rate better than 1 *mc*. Some alloy junction type transistors are also good for lower speed *nor* circuits if storage time is minimized (e.g., by using diode clamping or reverse base drive). For example, 5 to 10 *mc* alloy junction transistors are good for circuit speeds of 100-200 *kc*.

Some design information of multi-level *RTL* circuits can be found in reference (1). In the analysis, the base-emitter and collector-emitter voltage drops are assumed negligible when a transistor is turned *on*. In the design procedure, if I_{co} (maximum), beta (minimum) of a certain type of transistor, and m (level) are given, a graphical solution may be used to determine the current or voltage-resistor ratio of the in-

puts and the bias. A typical design of a two transistor full adder circuit similar to that shown in *Fig. 6* was given, with marginal observation of voltage and temperature variations. Other multi-level circuits shown in the article can be constructed in a similar way; and most of them have been tried successfully.

In *RTL* applications, the transistors are operated as grounded emitter switches with rather low *dc* current gain which results from the design safety margin required in practical circuit operations. Therefore, it is very possible that one can select *npn* and *pnp* type transistors which are designed to work satisfactorily in complementary logic. It has been the intention of this article to show the merit of using complementary *RTL* circuits by referring to some practical examples which may prove to be useful.

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An Equipment for High Power Rectifier Evaluation

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The increase in sophistication and improvements in technique over the last few years have resulted in the general availability of high-current, high-voltage rectifiers. Both maker and user are now confronted with problems of testing these devices. The difficulties encountered using simple test methods are discussed as well as one of the solutions to this problem.

When the problem of rectifier testing arises, the first approach that suggests itself is the so-called "brute force" method. The method consists of specifying a transformer capable of supplying two rectifiers in a full wave configuration with the required forward current at the maximum rated PIV. Since the rectifier has a forward drop in the order of one volt, a limiting resistor must be installed to set the forward current to the test rating. The transformer must be rated at approximately:

$$KVA = 2\ E_{piv} \times I_{av}/\text{diode}$$

and the resistor must dissipate 2 $E_{piv} \times I_{av}$/diode watts. We are now faced with the disturbing fact that in order to test two devices with power dissipations of approximately $I_{av} \times 2$ watts, test equipment must be rated at and dissipate approximately $2 \times I_{av}\ (E_{piv})$ watts.

The ratio of power required for the test, to that used, is then, $1/E_{piv}$, or the efficiency is $1/E_{piv} \times 100\%$.

As an example, if two 160-ampere, 500-volt diodes were tested in this manner, the efficiency would be approximately 0.2%, and approximately 160 *kw* would be dissipated in equipment heat. If this equipment were in use 40 hours a week, 50 weeks a year, 310,000 *kwh* would have been used. If the power was $.02/*kwh*, $6,200.00 would have been spent for 2,000 hours of test. If the facility were air-conditioned, approximately $12,000.00 would be spent removing this wasted power.

The most flexible system of this type would accommodate the highest voltage rectifiers that might be tested in the future as well as all present types. The addition of a variable transformer whose *kva* rating equals that of the transformer, would provide voltage control. Current control, however, could only be achieved by replacing the limiting resistor for each rectifier current rating to be tested. It is quickly apparent that the obvious simplicity of this method is more than negated by the excessive *kva* and power requirements as well as the lack of flexibility.

Rectifiers by their very nature have power ratings differing from one to four orders of magnitude in the forward and reverse directions. The equipment described in this article takes advantage of the difference in forward and reverse power requirements and provides flexibility in testing parameters. It has been designed for the evaluation of rectifiers in a current range from 5 to 200 amperes, with PIV's from 50 to 1500, by the principle of *ac* simulation. This technique offers flexibility coupled with appreciable power savings.

In simulation, a low-voltage, high-current transformer and a high-voltage, low-current transformer are switched across the rectifier in synchronism with the power line frequency. This type of test has been in extensive use in evaluating lower power rectifiers, using a mercury-wetted synchronous relay as the switch. (See *Fig. 1.*) The simulator test for high powered units uses the same concept; however, the switch is an ignitron.

The ignitron is a single-anode, mercury pool tube that conducts when the voltage between cathode and anode exceeds its threshold (usually 12 to 13 volts) and an exciting current is intro-

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duced between ignitor and cathode. The basic half-wave ignitron simulator circuit is shown in *Fig 2*. The time relationship of the circuit voltages and currents are shown in *Fig. 3*.

When the reverse voltage is positive with respect to ground, the reverse blocking diode conducts and impresses reverse voltage on the rectifier being tested and the ignitron. Since the ignitron will not conduct without an ignition current, it holds off the reverse voltage. On the next half wave, the blocking diode is reverse biased by the negative reverse voltage, and the ignitor cathode (pool) is negative with respect to the ignitron anode. The ignition current pulse is supplied by a standard firing circuit phased to occur when the anode-to-cathode potential is approximately 13 volts. At this time the ignitron conducts and forward current is passed through the rectifier on test.

The equipment illustrated in *Fig. 4* is of the same type but in full-wave configuration, with positions for four rectifiers; two in series for each half wave. The reverse voltage is switched to any one rectifier at a time (see *Fig. 5*). A small powerstat and a tap on the reverse transformer allow any reverse voltage between 50 and 1500 to be applied for test. A multi-range microammeter in the return leg of the reverse voltage supply measures average reverse current while a small series resistor provides oscilloscope monitoring. The transformer rating is:

$$\frac{E_{piv}}{2} \times I_{max.\ rev.} \times \frac{\pi}{2} = 1.1\ E_{piv}$$

This is increased to 150 *va* to reduce transformer regulation with load. The forward transformer must be specified to maintain a minimum forward current conduction angle. The angle depends on the conduction threshold and peak forward voltage:

$$\phi = 180^\circ - 2 \sin^{-1}\left(\frac{E_{\text{threshold}}}{\sqrt{2}\ E_{rms}}\right)$$

The Electronic Industries Association Standards Proposal No. 665 (approved by the JEDEC Semiconductor Device Council) specifies that the conduction angle be between 180° and 130°. Assuming a minimum angle of 150° and transposing the equation for ϕ,

$$\frac{E_{\text{threshold}}}{\sqrt{2}\ E_{rms}} = \sin 15^\circ = 0.259$$

For two diodes in series, assuming an ignition threshold of 13 volts and a diode threshold of 0.5 volts, $E_{rms} = 40$ volts. The forward transformer then is rated at 40-0-40 volts and 1.11 I_{av} for full wave operation.

$$\text{Transformer Rating } (kva) = 1.1 \times 80 \times I_{av} = 88\ I_a$$

The resistors in the center leg dissipate $2 \times 1.1 \times I_{av} \times E'_{rms}$.

Since the peak transformer voltage is reduced by the threshold effect to $40\sqrt{2} - 14 = 42.5$ volts, the *rms* voltage across the resistors cannot exceed 30 volts. (Hence E' instead of E.)

The resistors then dissipate a maximum of $66 \times I_{av}$ watts.

If we now re-examine the test for the 160-ampere, 500 PIV unit, the power required and dissipated to test two or four (since they are in series) is:

Forward	$= 66 \times I_{av} \approx$	10.6 *kw*
Reverse	$\approx$	.1 *kw*
Controls	$\approx$	1 *kw*
Total	$\approx$	12 *kw*

This is 12 *kw* compared to the brute force requirements of 160 *kw*.

Aside from the power consideration this type of test set is extremely flexible, allowing independent control of reverse voltage (by means of a small powerstat) and forward current (with an adjustable load-voltage arrangement).

Since the forward transformer voltage is constant, the drop across the re-

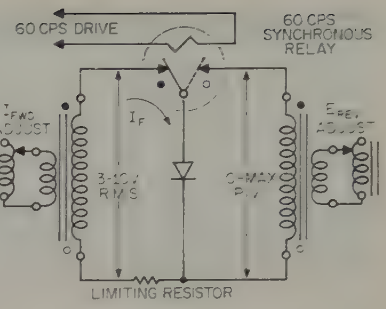


Fig. 1—Relay switching.

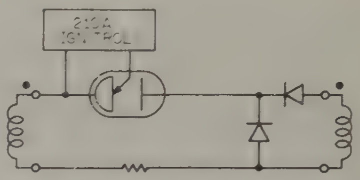


Fig. 2—Half-wave ignitron.

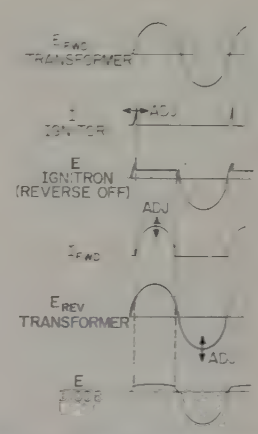


Fig. 3—Time relationships.

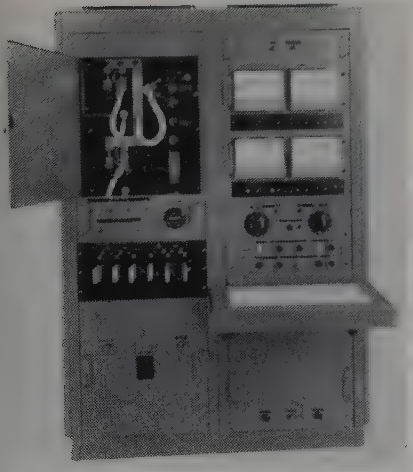


Fig. 4—Photo of the test equipment.

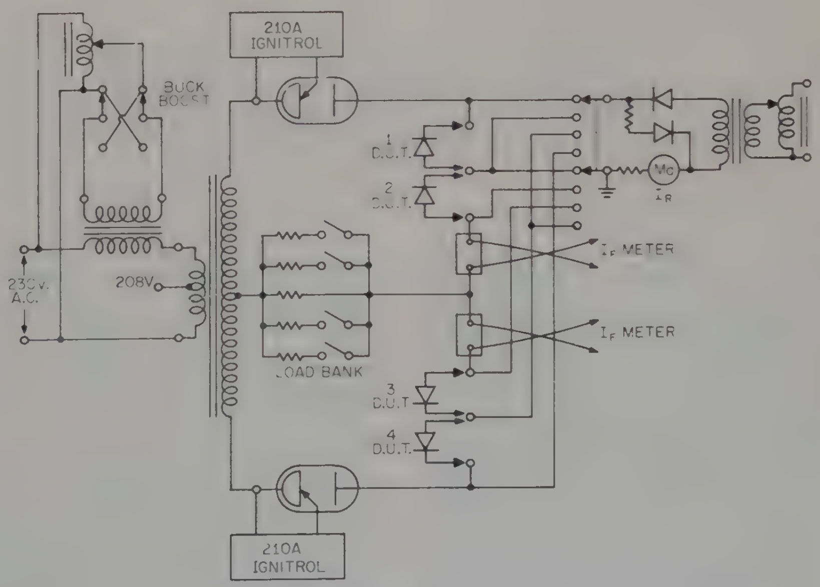
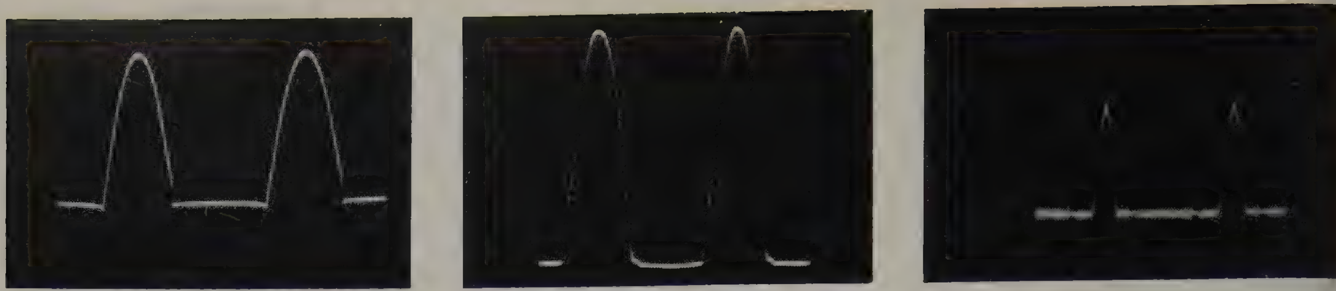


Fig. 5—Simplified schematic of the test set.



(a) (b) (c)

Fig. 6.—Oscilloscope photographs. (a) Forward current, 25 A. (b) Voltage across rectifier under test—30 A. forward, 100 volts reverse. (c) Reverse current at Zener conduction.

sistive load is constant. This favors a simple parallel load bank arrangement for forward current control. The limited-range buck-boost arrangement not only corrects for line variations but is used for a fine current trim between the small current step increments.

The simulator configuration is a two-branch circuit, lending itself to accurate measurements of reverse current to within $\pm$ 3 μa. even when forward currents of 200 amperes are being circulated.

The design and construction of the test instrument described takes into account ignitron ratings, excitation requirements for minimum I_{fd} cooling water resistance to ground, stray *ac* leakage, transformer phase shift, and discharge of the rectifiers' stored charge after the peak inverse voltage is reached.

Fig. 6 shows oscilloscope photographs taken during the operation of the equipment.

Simple modification of the equipment allows several other features to be added. A sharp leading-edge reverse voltage may be introduced by replacing the reverse blocking diode with a thyratron; forward conduction angle may be varied with the phase of the ignition pulse; surge testing may be incorporated with the addition of a small ignitron and new load configuration.

Specifications of the dynamic test set are as follows:

Input: 208/230 volts, 60 *cps*, 32 *kva* single phase.

Output: Four rectifier positions, 200 amperes average d.c., 1500 *piv* at any of the four positions, one at a time.

Metering: 7″, mirror scale, 1%, with knife-edge pointers as follows:
- I_{fd} 0-20/200 amperes d.c.
- E_{rev} 0-500/1500 *piv*
- I_r 0-250 *μa.*/2.5 *ma.*/25 *ma.*/250 *ma.* d.c. average
- E_{fd} 0-5/10 peak volts forward drop.

Calibrating jacks are supplied for all instruments, with provision made for oscilloscope monitoring of the above parameters.

The Use of Silicon Junction Diodes for the Protection of A-C and D-C Meter Circuits

PETER G. DUCKER

The application of the non-linear characteristics of a silicon junction diode, operating in its forward or Zener region, to the protection of a-c and d-c meter circuits is described. Protection of d-c microammeters, voltmeters, a-c milliammeters and voltmeters are discussed, together with a note on the application of Zener diodes for expanding the scale of d-c voltmeters. A number of graphs fully illustrate the degree of protection expected with a silicon diode used in the described circuits.

IT IS AN ESTABLISHED FACT that sensitive low range *a*-c and *d*-c instruments can be easily damaged when their meter movements are subjected to overloads, in the order of three or four times the rated full scale deflection. This problem has been solved in the past partly by the application of thermal, or similar devices, which inherently require a trip and/or reset time.

It has been found that silicon diodes lend themselves ideally to this problem of overload protection. Being passive devices, they have an instantaneous action and do not have a reset time. As will be described in the following sections, either the non-linear characteristics of a forward biased diode, or the Zener region of a reverse biased diode can be used.

Pacific Semiconductors Inc.
Culver City, Calif.

Protection of D-C Microammeters

Figure 1 illustrates the forward characteristic of a typical silicon alloy diode. It can be seen that when the forward voltage E_f is less than 0.3 volts, the forward current I_f is in the neighborhood of 0.1 microamperes. Imagine this diode

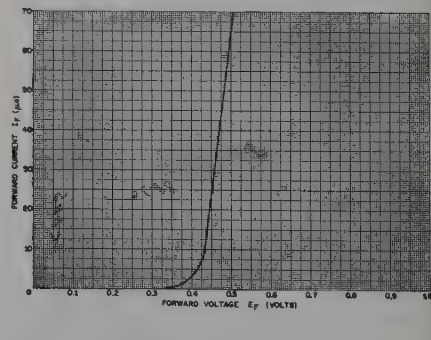


Fig. 1—Forward characteristic of a typical silicon alloy diode.

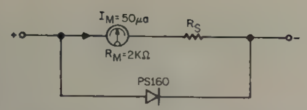


Fig. 2—Protecting a d-c microammeter.

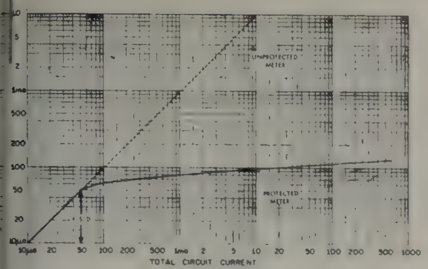


Fig. 3—Results obtained from circuit of Fig. 2.

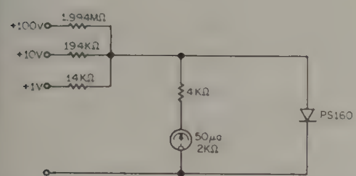


Fig. 4—Protective circuit for a 20,000 ohm/volt voltmeter.

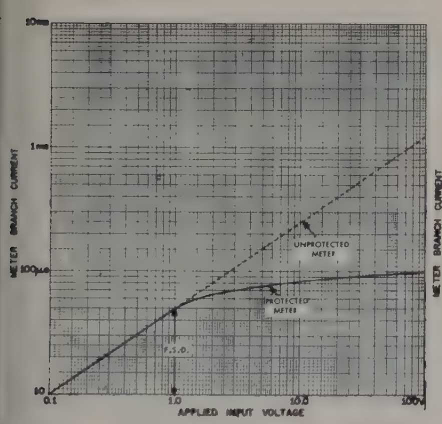


Fig. 5—Results obtained from circuit of Fig. 4.

in parallel with a 50 μa meter, and it will be evident that the shunting effect of the diode will not introduce any measurable error to the full scale deflection of the meter. In fact the error would be appreciably less than the rated full scale deflection tolerance of the meter. However, if the meter is overloaded and causes the terminal voltage of the meter to exceed 0.3 volt, the diode will begin to conduct and as far as the meter is concerned, the diode will behave as a short circuit.

Most microammeters with a full scale deflection of 50 μa, have an internal resistance of 2000 ohms. This represents a full scale deflection of 0.1 volts. Since we want the diode to conduct as soon as possible to carry the excess current, a resistance R_s is used in series with the meter to increase the terminal voltage to almost that of the conduction voltage of the diode. This circuit is shown in *Fig. 2*, illustrating a Model 27 Simpson Microammeter with a full scale deflection of 50 μa and internal resistance R_M of 2000 ohms.

The value of R_s is found from the following equation:

$$R_s = \frac{E_f}{I_M} - R_M$$

where I_M = Full scale deflection of the microammeter, in amps.

R_M = Internal resistance of meter, in ohms.

E_f = Point of beginning conduction of diode, typically 0.3 volts.

Then for our example,

$$R = \frac{0.3}{50 \times 10^{-6}} - 2000 = 4000 \text{ ohms}$$

The results obtained using this circuit are shown graphically in *Fig. 3*.

The curve shows that when the total circuit current is 500 *ma* (limited by maximum continuous rated forward current of PS160) the meter is only subjected to 134 μa. This means that when 10,000 times the rated meter current flows in the circuit the meter is only overloaded by a factor of 134/50=2.68. This is within the range of overload normally tolerated by this type of instrument.

The PS160 diode will tolerate surge currents of up to 8.0 amps for 3 milliseconds, which represents an overload of 160,000 times.

Protection of D-C Voltmeters

1) *Use of Diode Forward Characteristics*

The 50 microampere meter discussed in the previous section can be adapted to a 20,000 ohm/volt voltmeter by the addition of suitable voltage multiplier resistors. The circuit is illustrated in *Fig. 4*. The results obtained using this circuit are shown graphically in *Fig. 5*.

The one volt input was selected, and it can be seen that with 100 volts applied, i.e. 100 times rated input voltage, the meter is only overloaded by a factor of 100/50=2.0.

2) *Use of Zener Diode Characteristics*

Fig. 6 illustrates the Zener characteristics of a PS6469 Zener diode. A typical protective circuit using this diode is shown in *Fig. 7*. The results obtained using this circuit are shown graphically in *Fig. 8*.

Using the 10 volt input, it can be seen that with 1000 volts applied, i.e. 100 times rated input voltage, the meter is only overloaded by a factor of 70/50 =1.4.

The value of R_s is found from the following equation:

$$R_s = \frac{E_z}{I_M} - R_M$$

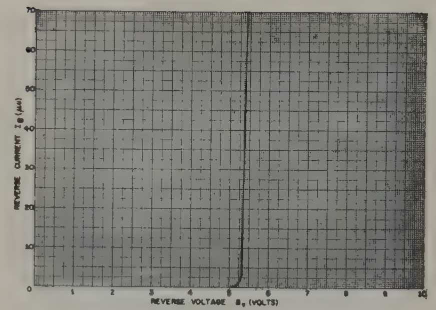


Fig. 6—Characteristic of a PS6469 Zener diode.

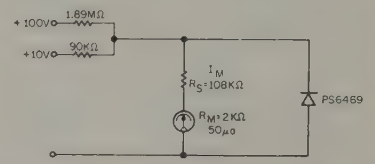


Fig. 7—Protective circuit using the PS6469 Zener diode.

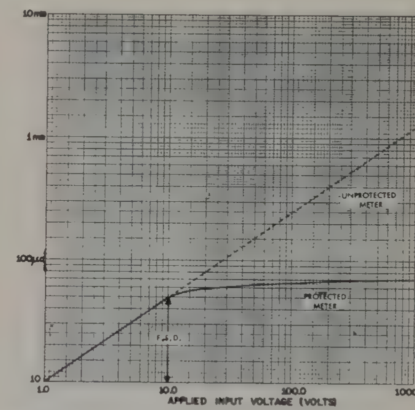


Fig. 8—Results obtained from circuit of Fig. 7.

where I_M = Full scale deflection of the microammeter, in amps.

R_M = Internal resistance of meter, in ohms.

E_z = Zener breakdown voltage of diode, in volts.

Then for our example,

$$R_s = \frac{5.5}{50 \times 10^{-6}} - 2000 = 108 \text{ K}\Omega$$

It is apparent that the Zener diode affords greater protection than a forward biased diode, as can be seen by comparing *Fig. 8* with *Fig. 5* respectively. However, the use of the Zener diode is restricted to d-c voltmeters where the input voltage scale is the same or greater than the Zener voltage. For example the PS6465 is the lowest voltage Zener normally produced with a Zener voltage of between 2.0 and 3.2 volts. This therefore restricts the lowest voltage scale of the voltmeter to >3.2 volts, for satisfactory protection of the meter.

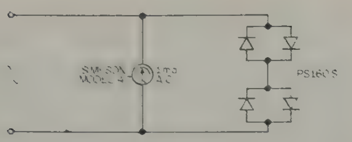


Fig. 9—Protecting an a-c milliammeter.

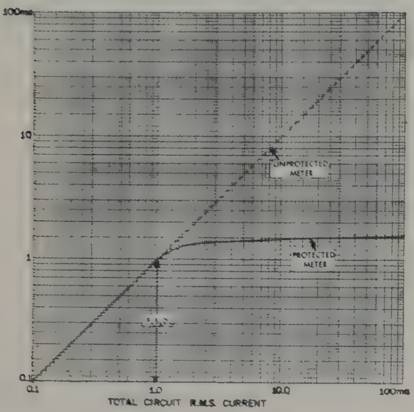


Fig. 10—Results obtained from circuit of Fig. 9.

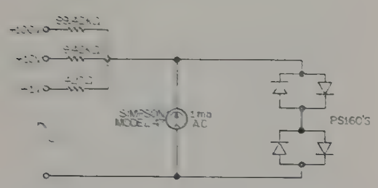


Fig. 11—Protecting an a-c voltmeter.

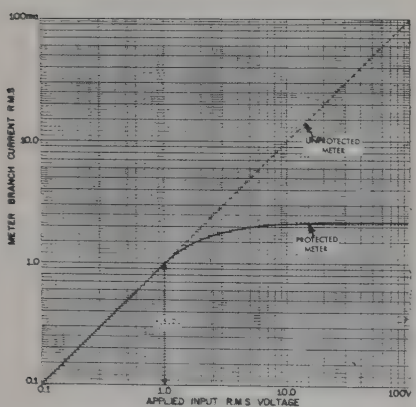


Fig. 12—Results obtained from circuit of Fig. 11.

Protection of A-C Milliammeters

A-C milliammeters can be protected by silicon diodes in a similar manner to that of *d-c* instrument protection. A circuit is shown in *Fig. 9*, utilizing a Simpson Model 47 one milliampere rectifier type *a-c* meter with a f.s.d. of 0.58 volts *rms*.

Since the meter has a terminal voltage of 0.58 *v. rms* at full scale deflection, two pairs of series connected PS160's are used without the addition of any series resistance in the meter leg.

If the meter happened to have had a lower f.s.d. voltage i.e. <0.58, it would have been necessary to include a resistance in series with the meter, to bring the voltage appearing across the rectifier leg to the region of "heavy" conduction of the diodes.

The results obtained using this circuit are shown in *Fig. 10*. It can be seen that when the circuit is overloaded 100 times the meter is only overloaded by a factor of 1.6/1.0=1.6.

Protection of A-C Voltmeters

1) *Use of Diode Forward Characteristics*

Utilizing the previous *a-c* milliampere circuit it is possible to design an *a-c* voltmeter by the addition of suitable multiplier resistors. Such a circuit is shown in *Fig. 11*. Results obtained using this circuit are shown in *Fig. 12*. Using the one volt input, with an overload of 100 times, i.e. 100 volts, the meter is only overloaded by a factor of 2.2/1.0= 2.2

2. *Use of Zener Diode Characteristics*

Fig. 13 ilustrates an *a-c* voltmeter circuit using two Zener diodes back-to-back. The results obtained using this circuit are shown in *Fig. 14*. Using the 10 volt input, with an overload of 100 times, i.e. 1000 volts, the meter is overloaded by a factor of 1.2/1=1.2.

The series resistance R_s is found from the following equation:

$$R_s = \frac{E_z - E_M}{I_M}$$

where E_z = Zener breakdown voltage of diode, in volts.

E_M = Voltage drop across meter for F.S.D., in volts.

I_M = F.S.D. of meter, in amps.

E_M = Voltage drop across meter for full scale deflection, in volts.

I_M = Full scale deflection of meter, in amps.

For our example:

$$R_s = \frac{5.5 - 0.58}{1 \times 10^{-3}} = 4.92\ \text{K}\Omega$$

Protection Against Reversed Polarity on D-C Instruments

The circuits described for *d-c* meters can all be adapted such that the meter is protected against overloads of reverse polarity. This is accomplished by adding a diode in parallel with the original diode, as shown in *Fig. 15*.

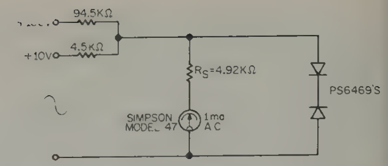


Fig. 13—A-C voltmeter using two Zener diodes back-to-back.

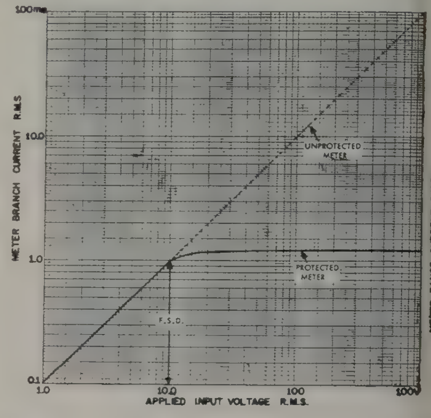


Fig. 14—Results obtained from circuit of Fig. 13.

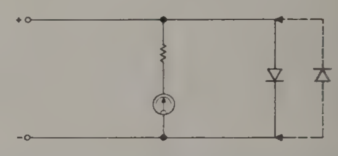


Fig. 15—Protecting a d-c meter against reversed polarity.

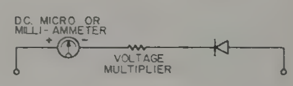


Fig. 16—Using the Zener diode for zero suppression.

Use of Zener Diodes to Expand the Scale of D-C Microammeters and Low Range Milliammeters

It is sometimes necessary to obtain measurements of voltage over a limited range. Zero suppressed instruments are used for this application. This means that all voltages below a certain value applied to the meter will not cause any movement of the pointer. The meter is calibrated so that the lowest voltage value takes the place of the conventional zero.

The Zener diode can be utilized for zero suppression as shown in *Fig. 16*. The Zener diode voltage determines the threshold voltage of the meter, and the voltage multiplier resistance determines the full scale deflection. Since the voltage scale is non-linear, it is necessary to calibrate the meter scale against some known standard.

APPLICATIONS ENGINEERING DIGESTS

APPLICATIONS ENGINEERING DIGEST NO. 60

(Circle 200 on Reader Service Card)

Power Transistor Series Voltage Regulator; Minneapolis-Honeywell Regulator Co., Semiconductor Products Div., Minneapolis, Minnesota. (J. F. Jacobs and J. L. Lamm)

The voltage regulator circuit, as shown, is designed to supply 21 volts output with 1% regulation, with inputs of 24 to 32 volts and load currents from zero to 3 amperes. These characteristics provide an output impedance of approximately 0.07 ohm. The system has short-circuit protection. The principle of operation is given and the circuit changes required for other output voltages and currents are explained.

CIRCUIT DESCRIPTION

Operation

A series voltage regulator operates by controlling the regulating impedance in series with the load. In the case of a transistor regulator, this variable impedance is a transistor. The control of the regulating transistor is obtained by comparing the output (load) voltage with a reference voltage, amplifying any difference in the compared values, and applying this amplified difference to the regulating transistor. The result is a tight closed loop in which the load current is proportioned to the difference between the measured load voltage and the reference voltage.

Function of Components

In the circuit of *Fig. 60.1*, D_1 determines the reference voltage. R_4 limits the current through D_1 to a nearly constant value. The combination of R_1, R_2 and R_3 represents the output voltage sensing network, a portion of which is compared to the voltage D_1. The voltage difference between D_1 and the portion of the output being compared to D_1 determines the bias on Q_3. This difference is amplified by Q_3 and Q_2 and applied to Q_1 where it is again amplified and used for control. R_5 is used to compensate for the difference voltage required to vary the load from no load to full load. R_6 is used to limit the current through Q_3.

Short-Circuit Protection

The circuit has inherent protection against accidental short circuits at the load. With a short circuit at the output, D_1 will not conduct and the only V_{BE3} bias obtainable would be that supplied by R_5 which would not be sufficient to turn Q_3 on. However, short-circuit protection will be lost using the basic circuit at a Q_1 mounting-base temperature above approximately 55°C. This is discussed further in the performance section.

Overload Protection

The basic circuit of *Fig. 60.1* has no useful overload protection but it may be built-in by increasing the value of R_4. The value of R_4 required to cause the circuit to shut down at some desired overload depends on the characteristic of the particular diode D_1 used. R_4 is adjusted (increased) so that at the point of desired overload shutdown the difference between the current through R_4 and the emitter current of Q_3 equals the diode "knee" current. Now, a further increase in load current and Q_3 emitter current causes the diode current to fall below the "knee" and the diode voltage collapses to turn off the circuit. There will be some sacrifice in regulation at normal loads when overload protection is built in due to operating on a less linear portion of the diode characteristic curve. To minimize the sacrifice in regulation, a diode with a sharp "knee" should be selected.

ADAPTATIONS

Voltage

By varying D_1, R_1, R_2, R_3, and R_4 the regulated output voltage may be varied to a large extent. As a general rule, the minimum load voltage should not be less than twice the voltage of D_1 in order that the current variation of D_1 be limited. The minimum output voltage of this circuit is therefore dependent upon the voltage rating available for the diode used in D_1.

The circuit may be arranged as shown in *Fig. 60.2* to permit output voltage adjustments from approximately 1 volt to 30 volts with a 32-volt supply. Since the reference diode is in the input side of the regulator, the current through it is more subject to input voltage variations than it is in the basic circuit, and consequently, the regulation is poorer; 2% is typical. With this circuit, special care must be taken to limit the power dissipation in Q_1.

Although the basic regulator circuit is designed to operate with loads from zero to 3 amperes, the load limit is dictated by the power capability rather than the current capability of the tetrode transistor. The power dissipated by Q_1 is determined by the difference between the maximum input voltage less the minimum load voltage less the voltage drop across D_2 multiplied by the maximum load current or:

$$P_T = [V_{in}\ (\text{max}) - V_L\ (\text{min})\ V_{D2}] I_L\ (\text{max})$$

The maximum junction temperature must not exceed 100°C and the temperature derating for the 3N45 is 1°C/w. With the values used P_T will be 30 watts and the maximum mounting base temperature will be 70°C. When lower mounting base temperatures are maintained, the maximum load current may be increased.

Current and Power

Both the current and power capabilities of the regulator may be increased by the same means, that is, by the paralleling of Q_1 transistors. *Fig. 60.3* shows the procedure for paralleling five tetrodes.

The paralleling of transistors for Q_1 will require a re-evaluation of the values of R_1, R_2 and R_3 to allow for the I_{CBO} leakage of the added tetrodes. As tetrodes are paralleled for Q_1, it may be necessary to either increase the circuit gain or provide closer compensation for V_{BE3} variation by means of increasing R_5. With the typical circuit gain of the basic circuit, additional gain will have to be added when three or more tetrodes are paralleled in order to maintain 1% regulation. Increasing

(Continued on p. 88)

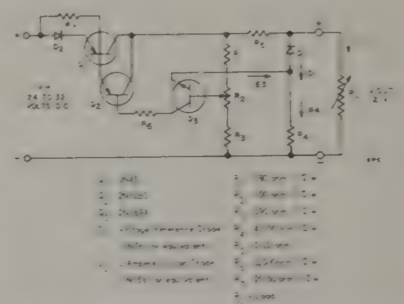


Fig. 60.1—Basic series regulator circuit.

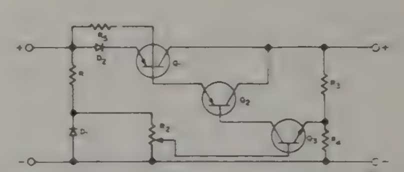


Fig. 60.2—Circuit providing adjustment of the output voltage.

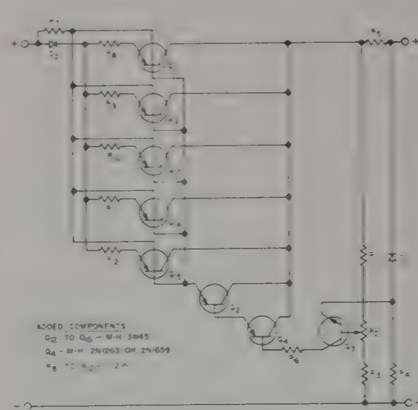


Fig. 60.3—Additional stage of gain employed when three or more tetrodes are paralleled.

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Nov. 25, 1958 to Dec. 23, 1958. In subsequent issues, patents issued from Dec. 23, 1958 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

November 25, 1958

2,861,932 Method of Treating Semiconductor Articles—R. G. Pohl. Assignee: The Rauland Corporation. Ultrasonic vibration is used in an electrolytic etching process for semiconductor bodies to produce highly consistent results.

2,862,060 Electrical Connecting Circuits—A. Ducamp, M. den Hertog. Assignee: International Standard Electric Corporation. A means of utlizing lockout arrangements to insure unique response to one electrical condition at a time.

2,862,109 Phototransistor Light Detector—A. P. Kruper. Assignee: Westinghouse Electric Corporation. A semiconductor light detector having an alternating voltage output signal which is relatively constant over a wide range of light intensity.

2.862.111 Automatic Paralling System—H. H. Richards Jr., L. R. Lowry, Jr. Assignee: Westinghouse Electric Corporation. A transistorized circuit for sensing phase and frequency differences between two generators or between a generator and an energized line.

2,862,113 Regenerative Transistor Amplifier—L. J. Kabell. Assignee: USA (Atomic Energy Commission). In computer applications an amplifier with reduced clock signal power requirements.

2,862,115 Semiconductor Circuits Controlling Devices—I. M. Ross. Assignee: Bell Telephone Laboratories. Means for controlling the current in the vicinity of a rectifying carrier region within a semiconductor body.

2,862.126 Radiation Sensitive Semiconducting Layer of Amorphous Selenium—M. Ploke, M. Keller. Assignee: Zeiss Ikon (Germany). An X-ray sensitive, 200-micron-thick layer of amorphous selenium is formed in a metal support plate in vacuum at a temperature below 125°F.

2,862,158 Semiconductor Device—J. P. Stelmak. R. E. Brown. Assignee: Westinghouse Electric Corporation. A junction transistor capable of use at power levels in excess of 150 milliwatts.

2.862,159 Conduction Cooled Rectifiers—W. Y. Walworth. Assignee: Raytheon Manufacturing Company. A rectifier structure wherein the unit of the temperature rise between the base and the hottest part of the rectifier is approximately 10°C.

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

2,862,160 Light Sensitive Device and Method of Making the Same—B. Ross. Assignee: Hoffman Electronics Corporation. The method of making a semiconductive light sensitive device which can function as a photovoltaic cell or as a phototransistor.

2,862,171 Control Apparatus—W. A. Freeborn. Assignee: Minneapolis Honeywell Regulator Company. A transistorized circuit for modulating an alternating current with a direct current.

2,862,175 Transistor Controlled Voltage Regulator For a Generator—J. H. Guyton, E. G. Roka. Assignee: General Motors Corporation. A *d-c* generator voltage regulating system including a transistor controlled generator field which control varies the current flow through the field windings in accordance with the line voltage.

2,862,184 Semiconductor Translating Device—R. L. Longini. Assignee: Westinghouse Electric Corporation. The application of electric and magnetic fields to a semiconductive body produces an output voltage which is independent of temperature variations, load, and Hall voltage across the semiconductor, and depends only on the field magnitudes.

2,862,189 Hall Voltage Device For Translating Electric Magnitudes—F. Kuhrt. Assignee: Siemens Schuckertwerke Aktiengesellschaft (Germany). A method of nullifying the remanence of the magnetic field system of a Hall voltage generator by use of a high frequency alternating current.

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2,862,416 Light Intensity Measuring Device Including Semiconductor Translating Circuit—W. C. Curtis. Assignee: General Electric Company. A frequency modulation system in which a photo sensitive semiconductor device in an oscillator circuit causes frequency variations in accordance with the light intensity incident thereon.

2,862,470 Transistor Mold Assemblies—J. R. Williams. Assignee: Raytheon Manufacturing Company. A mold assembly for concurrently fusing emitter, collector, and base materials to a crystal chip of semiconductor material.

2,862,787 Process and Apparatus for the Preparation of Semiconductors From Arsenides and Phosphides and Detectors Formed Therefrom—P. F. Seguin, F. F. Gans. Assignee: None. A method involving combining compound constituents in the gaseous phase.

2,862,840 Semiconductor Devices—A. P. Kordalewski. Assignee: General Electric Company. In an alloy junction transistor having a high ratio of majority carrier concentration in the emitter to that in the base, a junction formed between germanium and an indium aluminum alloy.

2,863,008 Stabilized Amplifier—E. Keonjian. Assignee: General Electric Company. Tandem connected solid state amplifiers in which transistor characteristics are temperature stabilized.

2,863,045 Semiconductor Mixing Circuits—V. P. Mathis, J. J. Suran. Assignee: General Electric Company. Converter and mixing circuits utilizing single rectifying semiconductor devices.

2,863,056 Semiconductor Devices—J. I. Pankove. Assignee: Radio Corporation of America. A negative resistance switching or triggering device which has some of the characteristics of thyratron systems.

2,863,065 Reflex Circuit System—D. DeWitt, H. Sandler, R. C. Wittenberg. Assignee: Radio Receptor Company, Inc. A transistorized reflex amplification system.

2,863,066 Reflex Circuit System—D. DeWitt, H. Sandler, R. C. Wittenberg. Assignee: Radio Receptor Company, Inc. A transistorized reflex amplification system.

2,863,068 Signal Responsive Network—S. K. Ghandi. Assignee: General Electric Company. A circuit used to initiate or damp shock waves in a resonant element or network.

2,863,069 Transistor Sweep Circuit—M. J. Campanella. Assignee: Radio Corporation of America. A uniform linear sawtooth signal wave generator circuit susceptible to timing by the application of a trigger or control pulse.

2,863,070 Double Base Diode Gated Amplifier—J. J. Suran, V. P. Mathis. Assignee: General Electric Company. A circuit in which a single semiconductor device is used as both a gate and an amplifier.

2,863,104 Semiconductor Components and Their Manufacture—R. Landron Jr. Assignee: Corning Glass Works. Method of hermetically sealing a transistor assembly in a vitreous housing.

2,863,105 Rectifying Device—B. Ross. As-

gnee: Hoffman Electronics Corporation. p-n junction power rectifier.

2,863,106 Crystal Rectifier and Manufacture Thereof—P. E. Lighty, J. J. Albanes, T. H. Gesell. Assignee: International Telephone and Telegraph Corporation. A point contact semiconductor diode which lends itself to manufacture by the combination of three individual subassemblies.

2,863,110 Transistor Testing Systems—L. Davis Jr. Assignee: Raytheon Manufacturing Company. A method for measuring the base width of a junction transistor during or after completion of the manufacturing process.

2,863,123 Transistor Control Circuit—W. R. Koch. Assignee: Radio Corporation of America. A control circuit using transistors of opposite conductivity type to achieve a wide range of control of the shunt impedance in a signal conveying system.

December 9, 1958

2,863,955 Direct Coupled Amplifiers—E. Keonjian. Assignee: General Electric Corporation. A temperature stabilized output, direct-coupled transistor amplifier.

2,863,957 Triad Transistor Amplifier—R. B. Hamilton. Assignee: Ryan Aeronautical Company. An amplifier circuit in which a negative coefficient resistor in series with a portion of the feedback circuit compensates for temperature variations.

2,863,995 Super-Regenerative Detector Circuit Using Transistors—W. F. Chow. Assignee: General Electric Corporation. A detector circuit using point contact transistors produces large *r-f* amplification and requires low power.

2,864,002 Transistor Detector—H. M. Strauke. Assignee: Bell Telephone Laboratories. A sensitive linear detector, one embodiment of which permits detection of very weak signals without preamplification.

2,864,006 Cooling Structure for Semiconductor Devices—E. O. Vandeven. Assignee: General Electric Company. A device in which the heat generating elements of the configuration are thermally connected to a heat radiator but are electrically insulated therefrom.

2,864,007 Transistor Trigger Circuit—C. L. Clapper. Assignee: International Business Machines Corporation. In a trigger circuit means are included for utilizing the output to integrate the input to the trigger.

2,864,053 Silicon Diode Error Detector—W. H. Woodworth. Assignee: U.S.A. (Navy Department). A device that senses the absolute value of a d-c voltage and provides an output voltage or current which will indicate the difference between the proper voltage and the sensed voltage.

2,864,062 Negative Resistance Using Transistors—J. S. Schaffner. Assignee: General Electric Company. A junction transistor configuration which provides a negative impedance characteristic over a wide frequency range.

December 16, 1958

2,864,139 Method and Apparatus for Producing Intermediate Semiconductor Product—C. Z. LeMay. Assignee: Texas Instruments Incorporated. Method of producing a semiconductor intermediate product containing sufficient quantities of impurity to insure accurate determination by weight of the content thereof.

2,864,729 Semiconducting Crystals for Rectifiers and Transistors and Its Method of Preparation—K. O. Seiler. Assignee: International Standard Electric Corporation. Method of producing *p-n* crystals which diminishes surface influences and which causes the blocking voltage to tend to the theoretical limit.

2,864,902 Amplifying Circuit Comprising A Plurality of Transistors—A. J. Van Overbeek. Assignee: North American Philips Co. Inc. A multistage transistor amplifier including a number of cascaded transistor amplifying stages in a grounded base configuration.

2,864,903 Transistor Amplifier With Gain Control—A. G. Becking, P. Blom, P. Boxnan. Assignee: North American Philips Company. A two-stage cascaded transistor amplifier.

2,864,904 Semiconductor Circuit—J. L. Jensen. Assignee: Minneapolis Honeywell Regulator Company. A composite transistor in which each member of the composite unit may be simultaneously cut off by the input signal.

2,864,905 Modulator-Demodulator Amplifier System—R. F. Grantges, J. Holzer. Assignee: None. A system wherein linear amplification results from the use of nonlinear amplifiers and wherein high power and good efficiency is achieved without nonlinear distortion.

2,864,961 Transistor Electronic Switch—R. D. Lohman, G. B. Herzog. Assignee: Radio Corporation of America. Means for selecting a signal from a plurality of sources and applying said signal to a single conveying circuit.

2,864,962 Semiconductor Apparatus—J. L. Jensen. Assignee: Minneapolis Honeywell Regulator Company. A multiposition transistor switching circuit used for activating a selected load device from several such devices in response to a signal.

2,864,975 Transistor Circuit for Operating a Relay—E. E. Sumner. Assignee: Bell Telephone Laboratories. Circuitry for protecting transistors in relay circuits from damage due to transient collector voltage overload.

2,864,978 Control Apparatus—A. I. Frank. Assignee: Minneapolis Honeywell Regulator Company. A phase discriminating relay control circuit utilizing a transistor as the control element.

2,864,980 Sealed Current Rectifier—D. L. Mueller, W. J. Martin Jr. Assignee: General Electric Company. Strain-free semiconductor rectifier, all enclosures of which provide access for cell decontamination prior to final hermetic sealing.

2,864,985 Electrical Control Apparatus—K. H. Beck. Assignee: Minneapolis Honeywell Regulator Company. A transistorized motor control device for controlling a reversible rotating field motor.

December 23, 1958

2,835,082 Semiconductor Mount and Method—P. E. Gates. Assignee: Sylvania Electric Products Incorporated. A mount is obtained by subjecting a support plate coated with a germanium layer to a criss-cross cutting operation thereby producing rectangular bars with a semiconductive element at one end thereof.

2,865,712 Process for Recovery of Germanium Sulphide—L. J. Bechaud Jr., P. Malozemoff. Assignee: Tsumeb Corp. Ltd. (Southwest Africa). Means for recovering germanium sulphide from sulphide concentrates containing copper, lead, and germanium.

2,865,793 Method of Making Electrical Connection to Semiconductive Selenide or Telluride—D. deNoble. Assignee: North American Philips Corporation. A method involving the deposition of a precious metal layer to the selenide or telluride body.

2,865,794 Semiconductive Device With Telluride Containing Ohmic Contact and Method of Forming The Same—F. A. Kroger, D. deNoble. Assignee: North American Philips Co. Inc. A method of making an ohmic contact by fusing tellurium metal to a telluride semiconductor in a nitrogen atmosphere.

2,865,996 Synchronizer For Telegraph Receivers—T. A. Hansen. Assignee: Teletype Corporation. A transistor controlled multiplex receiving distributor capable of maintaining synchronous operation with respect to the receipt of multiplex type telegraph signals.

2,866,017 Stabilized Signal Translating Circuits—J. P. Jones Jr. Assignee: Navigation Computer Corporation. Transistor translating circuit temperature stabilization by means of a temperature responsive impedance element.

2,866,103 Diode Gate and Sampling Circuit—J. T. Blake, A. L. Ely. Assignee: Bell Telephone Laboratories. A fast acting double-T-configuration gate circuit.

2,866,104 Frequency Divider Circuit—F. D. Biggam. Assignee: Teletype Corporation. A frequency divider with an output binary which operates after receipt of a predetermined number of input pulses and is then restored to the initial state upon receipt of another input pulse.

2,866,105 Transistor Logical Device—J. P. Eckert Jr. Assignee: Sperry Rand Corporation. A transistor amplifier in which the load is selectively keyed into and out of the circuit.

2,866,106 Voltage Sensitive Control Device—N. F. Schuh. Assignee: Westinghouse Electric Corporation. A transistorized, voltage sensitive, bistable operating, slow response device capable of time delay operation.

2,866.140 Grown Junction Transistors—M. E. Jones, E. D. Jackson, R. F. Stewart. Assignee: Texas Instruments Incorporated. Means of lowering the bulk collector resistance of grown junction silicon transistors.

2,866,178 Binary Devices—A. W. Lo, W. A. Helbig. Assignee: Radio Corporation of America. A binary device utilizing rectangular hysteresis elements as dynamic circuit components.

[To Be Continued]

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Dislocations and Brittle Fracture in Elemental and Compound Semiconductors	Acta Metallurgica Sept 1960	The predominant (110) cleavage plane of the III_b-V_b compounds has been explained by employing a dislocation model to account for the unique 3-fold symmetry of the crack pattern which results from indenting a (111) surface with a pointed conical diamond.	M. S. Abrahams L. Ekstrom
A Constant-Voltage Battery Charger	App & Industry AIEE Sept 1960	Charger uses silicon rectifiers and magnetic amplifiers; is insensitive to *a-c* supply fluctuations; and will regulate constant voltage from zero to full load.	C. H. Leet W. Zug
Printed Circuits Containing Resistors, Part I	Brit Comm & Elecncs Sept 1960	Germanium and germanium/metal alloy films were investigated as possible resistance materials. An account is given of methods of producing these films.	P. A. B. Toombs
Static Control for a Mechanically Regulated D-C Supply	Comm & Elecncs AIEE Sept 1960	New *d-c* sensing control described uses two high-gain transistor magnetic bistable amplifiers and a varistor detector.	H. J. Abrams J. F. Brubaker
High-Speed Switching Transistors	Elecl Design News Sept 1960	Discussion of equations for conventional transition times and when the transistor is driven from a constant current source.	C. D. Simmons
Transients in Direct Current Control Circuits Supplied from Transistors	Electric Tech (USSR) Nov 1960	Nature of phenomena during transients in inductive transistor circuits is discussed.	G. M. Kasprzhak E. L. Orkina
Investigation of Powerful Germanium Rectifiers	Electric Tech (USSR) Nov 1960	Dependence of the forward currents on voltage and temperature; saturation current and its dependence on temperature; capacitance; and the reverse branch of the V/A characteristic are discussed.	V. S. Bagayev
How to Account for Voltage Drops in Conducting Logic Diodes	Elecnc Design Sept 28 1960	A new method of determining the effect of conducting diodes on the output level of a complex gate is discussed.	C. W. Johnson
Multivibrator Gives Nanosecond Pulses with Variable Width	Elecnc Design Sept 14 1960	Using additional transistors to isolate key points in the conventional monostable multivibrator circuit improves performance in the nanosecond region.	R. Roy
How to Make Your Own Transistor Parameter Converter	Elecnc Design Sept 14 1960	Construction details on a handy slide rule for converting from *L* to *T* parameters.	J. R. McDermott
Drive Circuit Design for High Speed Memories, Part II	Elecnc Equip Engg Sept 1960	Concluding article covers the inhibit circuit, read-write driver and address switch, and sense amplifier.	G. R. Gaschnig
How to Design Transistor Blocking Oscillators	Elecnc Equip Engg Sept 1960	Various methods of controlling pulse width, such as: utilizing saturation characteristics of transformers, capacitor charge, delay lines, and external gating of a transistor.	H. L. Morgan
Paralleling Power Transistors	Elecnc Equip Engg Sept 1960	Techniques provide proper values for emitter and base resistance and method for selecting the proper number of transistors to be used for a given circuit application.	R. J. Zelinka D. C. Mogen
Transistor Circuits . . . Driving the Beam Switching Tube	Elecnc Industries Sept 1960	High amplitude drive signals and impedance match are problems encountered when used with transistor logic. Successful solutions are presented.	E. J. Oelbermann A. E. Crecraft
Unconventional Power Converters	Elecnc Industries Sept 1960	Brief surveys on solid state and gaseous converters and generators; includes thermoelectric generators and solar cells.	C. M. Celent
Space Capsule Oscillator	Electronics Sept 16 1960	Produces 50 mW of 100 cycle audio output into a 600 ohm load.	N. Kling
High-Current Solid State Switches	Electronics Sept 16 1960	Description of transistor circuit based on hybrid multivibrator which energizes falling-sphere accelerometer.	C. H. Price Jr.
Generator Delivers Constant Current or Voltage Pulses	Electronics Sept 16 1960	Rectangular pulses provide means for testing and evaluating electroexplosive devices, and find application in studies of electrothermal parameters.	L. A. Rosenthal
Automatic Frequency Control with Reactance Transistors	Electronics Sept 30 1960	Automatic frequency control is obtained in a transistorized TV remote sync lock circuit by controlling bias on a reactance transistor.	Y. Fujimura N. Mii
Wideband F-M Receiver for Remote Aircraft Control	Electronics Sept 30 1960	Description of a transistorized receiver, 405 to 549 *mc*. Has a self-contained unit providing a demodulated audio output for coupling to a variety of decoding equipment.	T. L. Fischer
Sensitive Capacitance Intruder Alarm	Electronics Sept 30 1960	All semiconductor alarm detects intruder by sensing his body capacitance. System features bridge, phase-detector, and rate sensitive circuits.	S. M. Bagno
The Silicon Uni-Tunnel Diode	Hoffman Span Sept/Oct 1960	Characteristics charts and circuit applications are presented.	E. F. Koshinz
Voltage Regulator Diode Surge Ratings . . . 150 MW and 1 W Diodes	Hoffman Span Sept/Oct 1960	Curves are provided which can be used to compute the maximum allowable peak power with any type of input condition.	W. McDonald
A Description of the Tunnel Diode and its Application	IRE Trans Bdcastg Sept 1960	Basic physics of semiconductors discussed and applied to tunnel diode. Typical applications and basic circuit concepts presented.	J. J. Wentworth
Exact Design of Transistor RC Band-Pass Filters with Prescribed Active Parameter Insensitivity	IRE Tr Circuit Theory Sept 1960	The synthesis procedure is generalized so that it can be applied to nonideal practical active elements. Optimum design is defined. Sensitivity of transfer poles to variations of all four low-frequency active parameters is discussed.	I. M. Horowitz
Transistor Current Switching and Routing Techniques	IRE Tr Elecnc Comp Sept 1960	A system of circuit logic is described in which transistors are operated well out of saturation in order to effect maximum utilization of their speed.	D. B. Jarvis L. P. Morgan J. A. Weaver
Tunnel Diode Digital Circuitry	IRE Tr Elecnc Comp Sept 1960	Basic tunnel diode logic circuits are discussed. A tunnel diode flip-flop stage with marked advantages is described.	W. F. Chow

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Miniature Transistorized Crystal Controlled Precision Oscillators	IRE Tr Instrumtn Sept 1960	Two oscillators utilizing the 5-Mc GA-10752 precision AT-cut crystal unit are described in detail.	W. L. Smith
An Investigation of Long-Term Stability of Zener Voltage Reference	IRE Tr Instrumtn Sept 1960	Determination of the limit of stability that can be obtained with the silicon junction zener diode and the conditions necessary to maintain this stability.	R. P. Baker J. Nagy, Jr.
Resistivity Measurements of Semiconductors at 9000 Mc.	IRE Tr Instrumtn Sept 1960	Measurement is made of the reflection coefficient of the material when used to terminate a transmission line, or the transmission through a loosely-coupled high-Q cavity which is loaded by a test sample.	G. L. Allerton J. R. Seifert
A New Semiconductor Microwave Modulator	IRE Tr Microwave Sept 1960	The action depends on the increase of absorption with an increase of conductivity caused by the injection of excess minority carriers.	H. Jacobs
The Reliability of Transistors in Battery Portable Radio Receivers	IRE Tr Rel Qual Cont Sept 1960	An average field-failure rate of less than .01 percent per 1000 hours and a 2 to 5 percent rejection rate on incoming inspection or on the equipment manufacturer's production line is experienced.	R. M. Cohen
Germanium Crystals Grown from Hollow Cylindrical Seeds	J Appl Phys Sept 1960	The dislocation patterns of crystals grown from single crystal and polycrystalline hollow cylindrical seeds are examined.	R. C. Frank J. E. Thomas, Jr.
Drift Mobility of Neutron Irradiated *n*-Type Germanium	J Appl Phys Sept 1960	Drift mobility in neutron irradiated *n*-type germanium shows an initial increase for values of flux before the normal decrease prior to turning intrinsic.	W. H. Closser
Growth of GaAs Crystals in the (111) Polar Direction	J Appl Phys Sept 1960	The perfection of GaAs crystals grown in the (111) direction depends on the polarity of the seed crystal.	P. L. Moody H. C. Gatos M. C. Lavine
Thermal Conversion of *n*-Type GaAs	J Appl Phys Sept 1960	Empirical work tends to label copper as the causative agent in the thermal conversion of *n*-type to *p*-type GaAs.	J. J. Wysocki
Some Electrical Properties of Amorphous Selenium Films	J Appl Phys Sept 1960	A study is made of the dark current and photo-current characteristics of amorphous selenium and arsenic selenium alloy films.	R. A. Fotland
The Oscillistor New Type of Semiconductor Oscillator	J Appl Phys Sept 1960	The properties of a semiconductor employing a new type of magneto-oscillatory plasma effect is described.	R. D. Larrabee M. C. Steele
Statistics of the Occupation of Dislocation Acceptors (One Dimensional Interaction Statistics)	J Appl Phys Sept 1960	Occupation statistics for electrons on dislocation acceptors are derived considering only nearest neighbor interactions.	R. M. Broudy M. M. McClure
A PNP High-Frequency Silicon Transistor	JL Electrochem Soc Sept 1960	The need for complementary-type switching transistors has led to the development of a *p-n-p* silicon double-diffused transistor which is described in this paper.	W. A. Little
Donor Concentration at the Surface of a Diffused *N*-Type Layer on *P*-Type Germanium	JL Electrochem Soc Sept 1960	Four methods of evaluating the donor concentration at the surface of a diffused *n*-type layer on *p*-type germanium have been investigated.	R. Glang W. B. Easton
Electrochemiluminescence at a Silicon Anode in Contact with an Electrolyte	JL Electrochem Soc Sept 1960	In the study of stain films on single crystal silicon emission of light has been observed during the anodic oxidation of the film.	A. Gee
Study of Ball Milling and the Determination of Lattice Chloride in Zinc Sulfide	JL Electrochem Soc Sept 1960	Ball milling, followed by displacement washing, permits a distinction to be made between lattice chloride and internal surface chloride as parts of volume chloride.	A. Kremheller S. Faria A. K. Levine
Retention of Chloride in Zinc Sulfide during Phosphor Preparation	JL Electrochem Soc Sept 1960	A concentration cell procedure is employed to study chloride retention in zinc sulfide powders.	A. Kremheller
Error of Rectifier Type Milliameters in Low-Resistance Circuits	JL Scient Insts (Br) Sept 1960	The error, calculated by arithmetical integration is shown on a nomogram relating error, series resistance, and meter indication.	J. Wilbur-Ham W. E. K. Gibbs
Measurement of Thermal Diffusivity of Semiconductors by Angstrom's Method	JL Scient Insts (Br) Sept 1960	An apparatus for the accurate determination of the thermal diffusivity of semiconductors which utilizes the thermoelectric properties of such materials is described.	A. Green L. E. J. Cowles
Transistor Resistor Logic Circuits	Mullard Tech Comm Sept 1960	The operation of a basic transistor-resistor logic circuit is described in this article, and design and performance equations are derived.	P. D. T. Hawker
Transistor Circuits for Magnetic Matrix Stores	Mullard Tech Comm Sept 1960	A description is given of the drive and output circuits associated with coincident-current magnetic matrix storage systems.	G. C. Padwick
A Gas-Discharge Indicator Tube for Transistorized Decade Counting Circuits	Philips Tech Rev Aug 4 1960	Principles and description of a tube which responds to small signals delivered by transistor circuits.	T. P. J. Botden
A Transistor Cardiotachometer for Continuous Measurements on Working Persons	Philips Tech Rev Aug 30, 1960	Heart beats are converted into electrical pulses by arranging for a beam of light transmitted through the lobe of the ear to fall on a phototransistor.	G. A. Harten A. K. Koroncai
The Fruits and Foundations of Solid-State Research	Philips Tech Rev Sept 27 1960	Author illustrates the significance of the solid state in electrotechnical applications. He then surveys the evolution of the theory which forms the basis of any discussion of solid-state phenomena.	D. Polder
A Method of Growing Dislocation Free Germanium Crystals	Philips Tech Rev Sept 27 1960	These crystals can be produced by the pulling method if the diameter of the crystal grown from the seed is initially reduced to 1 or 2 mm.	B. Okkerse
The Thermal Conductivity of Impure InAs at High Temperatures	Philosophical Mag Sept 1960	The magnitude of the impurity resistance at high temperatures is discussed and the recent data on heavily doped InAs (Stuckes 1960) are analyzed.	F. W. Sheard
Electron Mobility and Scattering Processes in AgBr at Low Temperatures	Physical Review Sept 1 1960	The Hall effect for electrons released by light in high-purity crystals of AgBr has been studied experimentally in the temperature range 4° to 120°K.	D. C. Burnham F. C. Brown R. S. Knox
Cascade Capture of Electrons in Solids	Physical Review Sept 1 1960	Capture into excited states of large radius followed by a cascade of one-phonon transitions leads to cross sections of the right order of magnitude.	M. Lax
Solubility of Flaws in Heavily Doped Semiconductors	Physical Review Sept 1 1960	A simple model is presented on the basis of which the dependence of the solubility of a chemical imperfection can be understood in regard to its dependence upon the donor and acceptor concentration.	W. Shockley

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Photoconductivity in Gallium Sulfo-Selenide Solid Solutions	Physical Review Sept 1 1960	The photoconductivity characteristics of solid solutions of GaSe and GaS have been investigated for proportions of GaS between 10% and 50%.	R. H. Bube E. L. Lind
Effect of Shear on Impurity Conduction in n-Type Germanium	Physical Review Sept 15 1960	The change of impurity conduction of Ge containing antimony was measured as a function of shear strains produced by uniaxial tension and compression along [110].	H. Fritzsche
Change in Structure of Blue and Green Sulfide at Low Temperatures	Physical Review Sept 15 1960	The two fundamental fluorescenses observed in cadmium sulfide crystals subjected to ultraviolet excitation at low temperatures are classified according to wavelength.	L. S. Pedrotti D. C. Reynolds
Low-Temperature Impurity Conduction and Magnetoresistivity in n-Type Germanium	Physical Review Sept 15 1960	The resistivity of several light doped (Sb) n-type germanium samples have been calculated and compared with values measured at 2.5°K.	P. Csavinzky
Symmetrical Matrix Analysis of Parametric Amplifiers and Converters	Proc IRE Sept 1960	It is shown that the parametric amplifier and frequency converter can be described by four equations, the coefficients of which form a matrix which is symmetrical.	S. Deutsch
Theory of a Monolithic Null Device and Some Novel Circuits	Proc IRE Sept 1960	This paper discusses a new simple structure which performs the function of a twin-T network, i.e., a null output is produced at a single frequency.	W. M. Kaufman
Optimum Noise and Gain-Bandwidth Performance for a Practical One-Port Parametric Amplifier	Proc IRE Sept 1960	The amplifier is analyzed to determine the conditions under which minimum effective noise temperature and maximum gain-bandwidth product can be obtained.	J. C. Greene E. W. Sard
The Design of Varactor Diodes	RCA Review Sept 1960	This paper is concerned with diode designs aimed at obtaining optimum performance in a paramagnetic subharmonic oscillator circuit.	J. Hilibrand C. F. Stacker
Evaluation and Control of Diffused Impurity Layers in Germanium	RCA Review Sept 1960	The calculations reported are for n- and p-type impurities with a complementary-error-function (erfc) distribution in uniformly doped germanium of the opposite conductivity.	H. S. Veloric W. J. Greig
Simple Transistor Marginal Oscillator for Magnetic Resonance	Rev Scient Instmnts Sept 1960	A transistor marginal oscillator circuit for nuclear magnetic resonance is described.	B. Donnally T. M. Sanders, Jr.
Intercardiac Catheter Tip Piezoresistive Pressure Gauge	Rev Scient Instmnts Sept 1960	The unit uses a two-section piezoresistive element operated as a cantilever. Sensitivity is 0.16 mv/v/psi; frequency response is flat from 0 to 400 cps.	M. Traite W. Welkowitz R. Downs
Transparent Indium Contacts to CdS	Rev Scient Instmnts Sept 1960	Diffusion and sputtering techniques are described for applying low resistance, highly transparent, antireflecting electrical contacts to CdS.	Y. T. Sihvonen D. R. Boyd
A Transistor Pulse Code Repeater	Semiconductor Prods Sept 1960	A pulse amplifier, or repeater, for regenerating a train of pulses in a PCM cable system is described.	G. R. Partridge
A New Type 150 KC Binary-Quinary Decade Counter with Neon Display	Semiconductor Prods Sept 1960	A novel approach is used in this economical Bi-Qui decade to count to ten and to display this count using readily available low-cost neon lamps.	R. A. Hempel
High Gain Silicon Transistors	Semiconductor Prods Sept 1960	Cascaded transistors within single crystal elements are discussed. Device properties are described.	H. W. Henkels T. P. Nowalk
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Introduction to Semiconductor Theory and Reverse Breakdown, Part II	Semiconductor Prods Sept 1960	Topics discussed are: extrinsic conduction and p-n junctions. Electron energy diagrams illustrate the discussion.	C. A. Escoffery
Electrical Properties of Alloyed p-n Junctions in Silicon Carbide	Soviet Phys Sol State Sept 1960	A study is made of current voltage characteristics of p-n junctions in n-type silicon carbide between 20°C and 500° C.	T. E. Kharlamova G. F. Kholuyanov
Investigation of the Surface Electrical Conductivity of Single-Crystal Germanium	Soviet Phys Sol State Sept 1960	This study indicates that to reduce surface conductivity in germanium, p-type material should be coated with a polar laquer and n-type material should not.	V. A. Presnov V. F. Synorov
Electrical Properties of an Equimolecular InSb-GaSb Alloy	Soviet Phys Sol State Sept 1960	The effect of alloy formation on carrier mobility is discussed and a table of properties of InSb alloy is presented.	V. I. Ivanov-Omski B. T. Kolomiets
Hall Effect in Vitreous Materials of the $Tl_2Se\ As_2(Se, Te)_3$ System II	Soviet Phys Sol State Sept 1960	It is shown that the conductivity of vitreous semiconductors varies with composition and depends on the concentration of low mobility current carriers.	B. T. Kolomiets T. F. Nazarova
Line Structure of the Fundamental Absorbtion Edge in Single Crystals of Cadmium Selenide	Soviet Phys Sol State Sept 1960	The line structure of the absorbtion and reflection spectra of single crystal CdSe in the region of the long wave absorbtion edge is studied.	E. F. Gross V. V. Sobelev
High Level High Frequency Germanium Triodes	Soviet Phys Sol State Sept 1960	The thermal conversion of germanium, which has copper as an impurity, from n-tvpe to p-type, is employed in producing a high frequency germanium triode.	V. A. Struzhinskii
Dependence of the Volume Peltier Effect On Resistivity Gradients	Soviet Phys Sol State Sept 1960	A study is made of the dependence of the volume Peltier effect on the value of the resistivity gradients in single crystals of germanium.	P. I. Baranskii P. M. Kurilo
The Volume-Gradient Thompson Effect	Soviet Phys Sol State Sept 1960	Experimental study of the volume gradient Thompson effect in single crystals of germanium is made.	P. I. Baranskii
Injection Heat Transfer	Soviet Phys Sol State Sept 1960	Study is made of Peltier effect in a p-n junction diode under various conditions of recombination.	V. I. Stafeev
Secondary Electron Emission and Elastic Reflection of Electrons from Germanium Single Crystals at Small Electron Energies	Soviet Phys Sol State Sept 1960	A study of the secondary emission properties of germanium at small primary energies reveals differences between single crystals and polycrystalline surfaces.	A. R. Shul'man D. A. Ganichev
Effect of Trapping Levels of the Relaxation of Photoconductivity in CdS Monocrystals	Soviet Phys Sol State Sept 1960	Experiment indicates that photoconductivity in CdS results primarily from the recombination processes therein.	L. G. Paritskii S. M. Ryvkin
Energy Spectrum of Holes in Diamond-Type Crystals	Soviet Phys Sol State Sept 1960	A calculation, introducing spin-orbital interaction, is made of the energy spectrum for p-type germanium and silicon.	K. Ya. Shtivel'man

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
mputing the Integrals in the thod of Equivalent Orbitals and aluating the Valence Band rameters for Semiconductors of e $A^{III}B^{V}$ Type	Soviet Phys Sol State Sept 1960	Calculation of effective hole masses, valence band width and forbidden band widths of $A^{III}b^{V}$ compounds.	A. A. Nran'yan
the Theory of Collision Re- nbination in Semiconductors	Soviet Phys Sol State Sept 1960	A calculation is made of the magnitude of the exchange term in minority carrier capture, and an accounting of the effect of coulomb forces in capture by charged centers is accomplished.	V. L. Bonch-Bruevich Yu. V. Gulyaev
ture of Bulk Gradient EMF ising in Germanium in the esence of Current	Soviet Phys Sol State Sept 1960	A study is made of the variation of the bulk gradient *emf* with temperature and on its dependence upon the effective lifetime of minority current carriers.	
the Joint Solubility of the III d V Groups in Germanium	Tech Translations Sept 14 1960 $2.50 MDF G-179	No abstract. Order from Morris D. Friedman, Inc., P.O. Box 35, New Newton 65, Mass.	V. N. Glazov D. A. Petrov S. N. Chizhevskaya
e Thermoelectric Properties of agnetite in the Temperature Re- on from 80 to 400°K	Tech Translations Sept 14 1960 $2.50 MDF S-163	No abstract. Order from Morris D. Friedman, Inc., P.O. Box 35, New Newton 65, Mass.	A. A. Samokhvalov I. G. Fakidov
vestigation of the Thermal and ectrical Conductivity of Mono- d Poly-Crystals in the Region 100°C to the Temperature of usion	Tech Translations Sept 14 1960 $4.80 60-16508	The temperature dependence of the thermal conductivity and specific resistivity of lead, cadmium, zinc, tin, copper, and bismuth is discussed. Order from Photoduplication Service, Public Board Project, Lib. Congress, Wash. 25, D. C.	V. Ye Mikryukov S. N. Rabotnov
pplications of Semiconductors in strument Design	Tech Translations Sept 14 1960 $51.60 60-19026	Collection of articles by various authors (1958). Order from Photoduplication Service, Public Board Project, Lib. Congress, Wash. 25, D. C.	
erminology of Semiconductor lectronics	Tech Translations Sept 14 1960 $2.50 MDF F-123	No abstract. Order from Morris D. Friedman, Inc., P.O. Box 35, New Newton 65, Mass.	A. Ya. Fedotov
n the Nature of the Quasi-Binary ection in the Germanium Indium ntimony System	Tech Translations Sept 14 1960 $2.50 MDF 2-123	No abstract. Order from Morris D. Friedman, Inc., P.O. Box 35, New Newton 65, Mass.	B. G. Zhurkin
emiconductor Devices and Their pplications	Tech Translations Sept 14 1960 $92.40 60-19122	Thirty-six papers relate to a wide variety of devices, circuitry and measurements. Order from Photoduplication Service, Public Board Project, Lib. Congress, Wash. 25, D. C.	B. G. Santanovskay
ome Studies on Certain Methyl erivatives of Silicon Germanium nd Tin	U S Govt Res Repts Sept 16 1960 LC $3.00 PB 147716	Three papers on chemical properties infrared spectra and nuclear magnetic resonance of methyl derivatives of Group IVB elements.	M. P. Brown
omplementary Transistor Modu- ator	U S Govt Res Repts Sept 16 1960 LC $3.00 PB 148115	Theory and test results of modulator circuits in which the carrier furnishes the supply voltage for operation.	J. Grau B. Humbel
roceeding of The Symposium on olid State Masers	U S Govt Res Repts Sept 16 1960 LC $16.80 PB 147977	From a symposium at Fort Monmouth, New Jersey, June 1958.	U. S. Army Signal R & D Lab
esearch and Development of ermanium PNP Junction Switch- ng Transistors	U S Govt Res Repts Sept 16 1960 LC $12.30 PB 14973	Result of tests on switching ability and packaging are discussed.	P. L. Meretsky
ransistor Phase Detector For hase-Lock Stabilization of a 3,000 Mc/sec Klystron	U S Govt Res Repts Sept 16 1960 LC $1.80 PB 148140	A pair of 2N588 transistors are used to form an error signal which is applied to the repeller of a reflex klystron.	R. W. Zimmerer
Four-Quadrant Analog Voltage Multiplier	U S Govt Res Repts Sept 16 1960 LC $3.30 PB 146812	A four-quadrant multiplier employs a transistor-magnetic square-wave oscillator.	C. F. Ravilious
Application of Silicon Controlled Rectifiers To a D-C Servomotor	U S Govt Res Repts Sept 16 1960 LC $9.30 PB 147686	A fast well-damped accurate servo system is described.	C. Cantor
High Power Pulse Generation Using Semiconductors and Magnetic Cores	U S Govt Res Repts Sept 16 1960 LC $7.80 PB 148040	A magnetic pulse generator uses a controlled rectifier in the charging circuit and can be used as a radar modulator.	M. Lassiter
A Transistor-Magnetic Pulse Generator for Radar Modulator Applications	U S Govt Res Repts Sept 16 1960 LC $15.30 PB 148041	Detailed description of an experimental pulse generator.	A. Krinitz
Piezoresistivity in Semiconductors for Transducer Applications	U S Govt Res Repts Sept 16 1960 LC $6.30 PB 147675	Theoretical discussion of piezoresistive effect in semiconductors, particularly TiO_2 and PbTe, and device design illustrations.	L. E. Hollander, Jr G. L. Vick
Transistorized Two-Segment Commutator for a Direct Current Machine	U S Govt Res Repts Sept 16 1960 OTS $1.75 PB 161790	The development of a two-segment commutator which uses transistors for the commutator switches as well as for the control circuitry.	D. M. Eisenlohr
The Effect of Nuclear Radiations on Semiconductor Materials	U S Govt Res Repts Sept 16 1960 LC $7.80 PB 147101	A literature survey concludes that germanium is relatively radiation resistant.	J. W. Moody R. K. Willardson
The Effect of Nuclear Radiation on Semiconductors Materials (First Addendum)	U S Govt Res Repts Sept 16 1960 LC $6.30 PB 147101-S-1	The study develops serious discrepancies between theory and experiment.	L. W. Aukerman
Investigations of Surface Properties of Silicon and Other Semiconductors, Phase I and II	U S Govt Res Repts Sept 16 1960 LC $4.80 PB 147758	Measurements are made of the surface conductivity of germanium and silicon in a controlled atmosphere.	H. E. Farnsworth D. Haneman
Investigation of Large Area Solar Cells Utilizing Spheres of Silicon	U S Govt Res Repts Sept 16 1960 LC $7.80 PB 148111	A study of large area photovoltaic devices predicts 100% light utilization with loose packing of spheres.	E. L. Ralph H. F. Brekofsky
Research Investigation of Radiative Recombination and Lifetime in Semiconductors	U S Govt Res Repts Sept 16 1960 LC $6.30 PB 148032	Radiation recombination from germanium appears to be due to direct band to band hole-electron recombination.	C. V. Bocciarelli
Semiconducting Properties of Boron	U S Govt Res Repts Sept 16 1960 LC $10.80 PB 147866	Attempts are made to grow boron crystals by a solid state transformation process; x-ray analysis of the crystals are conducted.	V. P. Jacobsmeyer F. Gebhart E. F. Juenke
Research on Growing of Cadmium Sulphide for Dosimeter Purposes	U S Govt Res Repts Sept 16 1960 LC $9.30 PB 137662	Preparation of CdS crystals on a quartz substrate by sublimation recrystallization.	K. E. Bean J. E. Powderly

CHARACTERISTICS CHART of NEW TRANSISTORS

MANUFACTURERS (In Order of Code Letters)

ARA— Advanced Research Associates, Inc.
AEG— Allgemeine Elecktricitats-gesellschaft
AMP— Amperex Electronic Corp.
AEIE— Associated Electrical Industries Ediswan Div.
AEIL— Associated Electrical Industries Export
ATLB— Associated Transistors Ltd.
BEN— Bendix Corp.
CBS— CBS Electronics
CPC— C.P. Clare Transistor Corp.
CDLF— Compagnie des Lampes
CSF— Compagnie Generale
CRY— Crystalonics, Inc.
CTP— Clevite Transistor Products, Inc.
DEL— Delco Radio Div., General Motors Corp.
ELE— Electromation Co.
ETC— Electronic Transistor Corp.
FSC— Fairchild Semiconductor Corp.
FTHF— French Thompson-Houston Semiconductor Dept.
GECB— General Electric Co., Ltd.
GE— General Electric Co.
GIC— General Instrument Corp.
GEM— Great Eastern Mfg. Co.
HITJ— Hitachi Ltd., Mushashi Works
HIVB— Hivac Ltd.
HSD— Hoffman Semiconductor Div.
HUG— Hughes Aircraft Co.
IND— Industro Transistor Corp.
INTG— Intermetall
KSC— Kearfott Semiconductor Corp.
KOKJ— Kobe Kogyo Corp.
LCTF— Labortoire Central de Telecommunications
MIN— Minneapolis-Honeywell Regulator Co.
MISI— Mistral
MOT— Motorola, Inc.

MUL— Mullard Ltd.
NAC— National Semiconductor Corp.
NTLB— Newmarket Transistors Ltd.
NIPJ— Nippon Electric Co. Ltd.
PSI— Pacific Semiconductors, Inc.
PHI— Philco Corp., Lansdale Division, Semiconductor Operations
RAY— Raytheon Co.
RCA— Radio Corp. of America, Semiconductor Div.
RDR— Radio Development and Research
RADF— La Radiotechnique, Div. Tubes Electroniques
RHE— Rheem Semiconductor Corp.
ROSG— Dr. ing. Rudolph Rost
SANJ— Sanyo Electric Co. Ltd.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SGSI— Societa General Semiconduttori
SONY— Sony Corp.
SPE— Sperry Rand Corporation
SPR— Sprague Electric Co.
STCB— Standard Telephone & Cables, Ltd.
STCA— Standard Telephones and Cables Pty, Ltd.
TKAD— Suddeutsche Telefon-Apparate-, Kabel und Drahtwerke
SYL— Sylvania Electric Products Inc.
TOSJ— Tokyo Shibaura Electric Co.
TRA— Transitron Electronic Corp.
TFKG— Telefunken Ltd.
TI— Texas Instruments Incorporated
TIB— Texas Instruments Ltd.
TUN— Tung-Sol Electric, Inc.
UST— U. S. Transistor Corp.
WEC— Western Electric Co., Inc.
WTC— Western Transistor Corp.
WEST— Westinghouse Electric Corp.

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C. P_C (mw)	DERATING °C/W	V_{CB}	V_{CE}	Typical Characteristics $f_{\alpha b}$ (mc)	GAIN PARAMETER And (Condition)	GAIN VALUE	MFR. See Code
2N398A	1	PNPA	Ge	150	500	105	105	1.0	h_{fe}:I_e-5.0ma	20	MOT
2N696A	5	NPND	Si	800	220	60	35	80	h_{FE}:I_C-150ma	20-60	RHE
2N697A	5	NPND	Si	800	220	60	35	80	h_{FE}:I_C-150ma	40-120	RHE
2N699A	5	NPND	Si	800	220	120	60	80	h_{FE}:I_C-150ma	40-120	RHE
2N700A	4	PNPD	Ge	75	1000	25	25	300	PG at 30Mc	29db	MOT
2N705A	5	PNPD	Ge	150	500	15	15	300	h_{fe}:I_e- 10ma	40	MOT
2N828	5	PNPE	Ge	150	500	15	15	400	h_{fe}:I_e- 10ma	40	MOT
2N858	5	PNPA	Si	150	770	40	40	14#	h_{FE}:I_C-5.0ma	20	PHI
2N859	5	PNPA	Si	150	770	40	40	14#	h_{FE}:I_C-5.0ma	35	PHI
2N860	5	PNPA	Si	150	770	25	25	14#	h_{FE}:I_C-5.0ma	20	PHI
2N861	5	PNPA	Si	150	770	25	25	22#	h_{FE}:I_C-5.0ma	35	PHI
2N862	5	PNPA	Si	150	770	15	15	14#	h_{FE}:I_C-5.0ma	20	PHI
2N863	5	PNPA	Si	150	770	15	15	22#	h_{FE}:I_C-5.0ma	35	PHI
2N864	5	PNPA	Si	150	770	6.0	6.0	22#	h_{FE}:I_C-5.0ma	35	PHI
2N865	1,5	PNPA	Si	150	770	10	6.0	52#	h_{FE}:I_C-1.0ma	75	PHI
2N1185	1	PNPA	Ge	200	375	45	30	3.0	h_{fe}:I_e-1.0ma	295	MOT
2N1186	1	PNPA	Ge	200	375	60	45	1.5	h_{fe}:I_e-1.0ma	50	MOT
2N1187	1	PNPA	Ge	200	375	60	45	2.0	h_{fe}:I_e-1.0ma	85	MOT
2N1188	1	PNPA	Ge	200	375	60	45	2.5	h_{fe}:I_e-1.0ma	155	MOT
2N1194	1	PNPA	Ge	200	375	45	30	3.0	h_{fe}:I_e-1.0ma	345	MOT
2N1252A	2	NPND	Si	800	220	60	30	80	h_{FE}:I_C-150ma	15-45	RHE
2N1253A	5	NPND	Si	800	220	60	30	80	h_{FE}:I_C-150ma	30-90	RHE

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C. P_C (mw)	DERATING °C/W	V_{CB}	V_{CE}	Typical Characteristics $f_{\alpha b}$ (mc)	GAIN PARAMETER And (Condition)	GAIN VALUE	MFR. See Code
2N1838	5	NPNMe	Si	2.0	75	45	30	190	h_{FE}:I_C-150ma	40-150	PSI
2N1839	5	NPNMe	Si	2.0	75	45	30	170	h_{FE}:I_C-150ma	12-50	PSI
2N1840	5	NPNMe	Si	2.0	75	25	20	150	h_{FE}:I_C-150ma	10min	PSI
2N1864	4	PNPMAD	Ge	60	1250	20	20	125*	h_{fe}:I_C-1.0ma	70	PHI
2N1865	4	PNPMAD	Ge	60	1250	20	20	235*	h_{fe}:I_C-1.0ma	25min	PHI
2N1866	4	PNPMAD	Ge	60	1250	35	35	235*	h_{fe}:I_C-1.0ma	25min	PHI
2N1867	4	PNPMAD	Ge	60	1250	35	35	235*	h_{fe}:I_C-1.0ma	10min	PHI
2N1868	4	PNPMAD	Ge	60	1250	20	20	700*	h_{FE}:I_C-2.0ma	33	PHI
2N1886	3	A	Si	40W	3.5	60	60	10	h_{FE}:I_C-500ma	40	TRA
2N1893	2,3,4,5	NPNPL	Si	3.0W	58.3Ø	120	100	110	h_{FE}:I_C-150ma	65Ø	FSC
2N1899	3,4	NPNMe	Si	125	1.0	140	100	50	h_{FE}:I_C- 10A	10min	PSI
2N1900	3,4	NPNMe	Si	125	1.0	140	100	50	h_{FE}:I_C- 10A	10-20	PSI
2N1901	3,4	NPNMe	Si	125	1.0	140	100	50	h_{FE}:I_C- 10A	15-40	PSI
2SA168A	4	PNPA	Ge	175		20	18	9.0			NIPJ
2SA238	4	PNPD	Ge	200		25	20	700	PG at 5.0ma,70Mc	17db	NIPJ
2SB218	5	PNPA	Ge	225	270	80	40	3.0	h_{FE}:I_C-200ma	50	NIPJ
2SB219	2	PNPA	Ge	225	270	30	20	1.5	h_{FE}:I_C- 20ma	31	NIPJ
2SB220	2	PNPA	Ge	225	270	30	20	2.0	h_{FE}:I_C- 20ma	50	NIPJ
2SB221	2	PNPA	Ge	225	270	30	20	2.0	h_{FE}:I_C- 20ma	72	NIPJ
2SB222	2	PNPA	Ge	225	270	30	20	2.5	h_{FE}:I_C- 20ma	97	NIPJ
2SB223	2	PNPA	Ge	225	270	30	20	3.0	h_{FE}:I_C- 20ma	150	NIPJ
2SB224	2	PNPA	Ge	225	270	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

2N1710	3,4	NPNMe	Si	13	11.5	60	45	210	PG at 30Mc	10db	PSI
2N1742	4	PNPMAD	Ge	60	1250	20	20	1K*	h_{FE}: I_C-2.0ma	33	PHI
2N1743	4	PNPMAD	Ge	60	1250	20	20	1K*	h_{FE}: I_C-2.0ma	33	PHI
2N1744	4	PNPMAD	Ge	60	1250	20	20	1K*	h_{FE}: I_C-2.0ma	33	PHI
2N1745	4	PNPMAD	Ge	60	1250	20	20	700*	h_{FE}: I_C-2.0ma	33	PHI
2M1746	5	PNPMAD	Ge	60	1250	20	20	235*	h_{FE}: I_C-1.0ma	60	PHI
2N1747	5	PNPMAD	Ge	60	1250	20	20	235*	h_{FE}: I_C-1.0ma	60	PHI
2N1748	12	PNPMAD	Ge	60	1250	20	20	115#	h_{fe}: I_C-1.0ma	45	PHI
2N1748A	12	PNPMAD	Ge	60	1250	20	20	136#	h_{fe}: I_C-1.0ma	70	PHI
2N1749	12	PNPMAD	Ge	60	1250	40	40	115#	h_{fe}: I_C-1.0ma	45	PHI
2N1750	1	PNPS	Ge	15	2000	14	6.0	50*	h_{fe}: I_C-.50ma	30	PHI
2N1752	13	PNPMAD	Ge	60	1250	12	12	100*	h_{fe}: I_C-1.0ma	250	PHI
2N1754	5	PNPMAD	Ge	50	1300	13	13	100#	h_{FE}: I_C- 40ma	50	PHI
2N1785	4	PNPMAD	Ge	45	1330	10	10	125*	h_{FE}: I_C-1.0ma	60	PHI
2N1786	4	PNPMAD	Ge	45	1330	10	10	125*	h_{FE}: I_C-1.0ma	60	PHI
2N1787	4	PNPMAD	Ge	45	1330	15	15	125*	h_{FE}: I_C-1.0ma	60	PHI
2N1788	4	PNPMAD	Ge	60	1250	35	35	150*	h_{FE}: I_C-1.0ma	60	PHI
2N1789	4	PNPMAD	Ge	60	1250	35	35	150*	h_{FE}: I_C-1.0ma	15min	PHI
2N1790	4	PNPMAD	Ge	60	1250	35	35	150*	h_{FE}: I_C-1.0ma	60	PHI
2N1837	5	NPNMe	Si	2.0	75	80	50	210	h_{FE}: I_C-150ma	40-120	PSI

GET881	5	A	Ge	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	h_{FE}: 25ma	65	GECB
GET882	5	A	Ge	75	650	15	10	15	h_{FE}: 25ma	50	GECB
GET883	4	A	Ge	75	650	15	10	6.0	h_{fe}: 1.0ma	50	GECB
GET884	4	A	Ge	75	650	15	10	15	h_{fe}: 1.0ma	70	GECB
GET885	5	A	Ge	75	650	15	10	20	h_{FE}: 25ma	90	GECB
KGS1000	2	PNPA	Ge	200	350	10		1.00∅	h_{fe}: I_e-1.0ma	15	KSC
KGS1001	2	PNPA	Ge	200	350	15		5.00	h_{fe}: I_e-1.0ma	30	KSC
KGS1002	2	PNPA	Ge	200	350	15		8.00	h_{fe}: I_e-1.0ma	50	KSC
KGS1003	2	PNPA	Ge	200	350	15		10	h_{fe}: I_e-1.0ma	90	KSC
PT600	3,5	NPNMe	Si	13	11.5	60	45	210	h_{FE}: I_C- 10A	15-45	PSI
PT601	3,5	NPNMe	Si	13	11.5	60	45	210	h_{FE}: I_C- 10A	30-90	PSI
PT850	5	NPNMe	Si	2.0	75	120	80	200	h_{FE}: I_C-150ma	40-120	PSI
ST721	5	D	Si	250	500	45	45	20	h_{fe}: 1.0ma	15	GECB
ST722	5	D	Si	250	500	45	45	23	h_{fe}: 1.0ma	30	GECB
ST723	5	D	Si	250	500	45	45	28	h_{fe}: 1.0ma	50	GECB

NOTATIONS

Under Use

1- Low power a-f equal to or less than 50 mw
2- Medium power a-f 50 mw and equal to or less than 500 mw
3- Power > 500 mw
4- r-f/i-f
5- Switching and Computer
6- Low Noise
7- Photo
8- Mixer
9- Local Oscillator
∅- Revised Spec.
10- Chopper
11- Matched Pair
12- Video Amplifier
13- TV Sync. Separator

Under Type

A- Alloyed
D- Diffused or Drift
E- Epitaxial Mesa
F- Fused
G- Grown
H- Hook Collector
M- Microalloy
PL- Planar
Me- Mesa
O- Other
S- Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
t - Tetrode

Under Gain Value

∅ - Pulsed

Under fab

* — Maximum Frequency
\# — Figure of Merit
Δ — $f_{\alpha e}$
∅ - Minimum
† — f_T (Gain Bandwidth Product)
∅— f_{os} max. (Max. freq. of oscillation)

Under Derating

∅ - Infinite heat sink

PREVIOUSLY REGISTERED NEWLY ANNOUNCED TRANSISTORS

ASSOCIATED TRANSISTORS LTD: 2N173, 2N215, 2N218, 2N269, 2N270, 2N274, [illegible], [illegible], 2N301, 2N301A 2N358, 2N384, 2N398, 2N404, 2N456, 2N457, 2N579, 2N580, 2N583, [illegible], [illegible], 2N586, 2N613, 2N644 2N645, [illegible], 2N706A, 2N1066, 2N1090, 2N1091, 2N1099, 2N1100, 2N1169, 2N1170, [illegible], 2N1178, [illegible] 2N1183, 2N1183A, 2N1183B, 2N1184, 2N1184A, 2N1184B, 2N1213, 2N1214, 2N1215, 2N1216, [illegible], 2N1226, 2N1300, 2N1301, 2N1319, 2N1384, 2N1396, 2N1397, 2N1479, 2N1480, 2N1481, 2N1482, 2N1483, 2N1484, 2N1485, 2N1486, 2N1487, 2N1488, 2N1489, 2N1490, 2N1491, 2N1492, 2N1493, 2N1683

[illegible] ELECTRONICS: 2N393, 2N1099

GENERAL INSTRUMENT: 2N393, 2N398, 2N499, 2N501, 2N501A, 2N502, [illegible], [illegible], 2N504, 2N588, 2N696, 2N697, 2N699, 2N706B, 2N1302, 2N1303, 2N1304, 2N1305, 2N1370, [illegible]

[illegible] SEMICONDUCTOR: 2N123, 2N396, 2N404, 2N404A, 2N413, 2N414, 2N415, 2N416, 2N417, [illegible] 2N428, 2N578 thru 2N582, 2N653, 2N658 thru 2N662, 2N1017, 2N1303, 2N1305, 2N1307, 2N1309

PACIFIC SEMICONDUCTORS: 2N698, 2N699, 2N706, 2N706A, 2N706B, 2N717, 2N718, 2N719, 2N720, 2N753

[illegible]: 2N1118A, 2N1429, 2N1500

[illegible] AND [illegible] PTY.LTD: 2N250, 2N251

SYLVANIA: 2N696, 2N697

CBS ELECTRONICS: 2N501, 2N501A

C P.CLARE TRANSISTOR: 2N396A, 2N404A, 2N413A, 2N414A, 2N1478, 2N1605, 2N1672

CLEVITE TRANSISTOR: 2N394, 2N395, 2N396, 2N396A, 2N397, 2N404, 2N404A, 2N418, 2N420, 2N420A, 2N456A, 2N457A, 2N458A, 2N1136A, 2N1136B, 2N1137A, 2N1137B, 2N1138A, 2N1138B

ELECTRONIC TRANSISTORS: 2N45, 2N77, 2N78A, 2N97, 2N98, 2N99, 2N207, 2N207A, 2N207B, 2N213, 2N214, 2N358A, 2N359, 2N377A, 2N385A, 2N388A, 2N404A, 2N413A, 2N414B, 2N414C, 2N467, 2N508, 2N523A, 2N570, 2N571, 2N572, 2N617, 2N631, 2N634A, 2N635A, 2N636A, 2N650A, 2N651A, 2N652, 2N652A, 2N655, 2N1018, 2N1093, 2N1124, 2N1125, 2N1128, 2N1129, 2N1130, 2N1171, 2N1191, 2N1192, 2N1193, 2N1251, 2N1265, 2N1273, 2N1274, 2N1299, 2N1306 thru 2N1309, 2N1313, 2N1366, 2N1367, 2N1378, 2N1379, 2N1380, 2N1381, 2N1382, 2N1408, 2N1413 thru 2N1416, 2N1431, 2N1471, 2N1473, 2N1478, 2N1605, 2N1614, 2N1624, 2N1672, 2N1673

GENERAL INSTRUMENT: 2N644, 2N645, 2N659

MISTRAL: This company is licensed by Compagnie Generale de T.S.F. and manufactures all types produced by Compagnie Generale de T.S.F.

NATIONAL SEMICONDUCTOR: 2N706B

RCA: 2N414, 2N497, 2N656, 2N794, 2N795, 2N796, 2N1480

RAYTHEON: 2N404A, 2N1605

SPRAGUE: 2N502, 2N502A

SYLVANIA: 2N651A, 2N741

WESTERN TRANSISTOR: 2N1034, 2N1035, 2N1036, 2N1037, 2N1375

CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

MANUFACTURERS

AEG— Allgemeine Elekticitats-Gesellschaft
ASC— American Semiconductor Corp.
AMP— Amperex Electronic Corp.
AEI— Associated Electrical Industries, Ltd.
BEN— Bendix Corp.
BER— Berkshire Corp.
BOM— Bomac Labs
BRA— Bradley Semiconductor Corp.
BRI— Britton Electronics Corp.
CBS— CBS Electronics
CDC— Continental Device Corp.
COD— Computer Diode Corp.
COL— Columbus Electronics Corp.
CON— Controls Co., of America
CTP— Clevite Transistor Products, Inc.
CSF— (Cosem) Cie Generale des Semi-Conducteurs
DEL— Delco Radio
DIC— Dickson Electronics Corp.
EEVB— English Electric Valve Co., Ltd.
ERI— Erie Resistor Corp.
ESP— Espey Mfg. and Electronics Corp.
FAN— Fansteel Metallurgical Corp.
FERB— Ferranti Ltd.
FSC— Fairchild Semiconductor Corp.
GAH— Gahagan, Inc.
GECB— General Electric Co., Ltd.
GE— General Electric Company, Semiconductor Div.
GELC— Canadian General Electric Co.
GIC— General Instrument Corp.
HAFO— Institutet for Halvedarforskning
HSD— Hoffman Semiconductor Division
HITJ— Hitachi Ltd., Mushashi Works
HUG— Hughes Products Division
ITC— Industro Transistor Corp.
INRB— International Rectifier Co., Ltd.
INRC— International Rectifier Corp.
IRC— International Resistance Co.
ITT— International Tel. & Tel. Corp.
KEM— Kemtron Electron Products, Inc.
MATJ— P. R. Mallory & Co., Inc.
MAL— Matushita Electronics Corp.
MIC— Microwave Associates, Inc.
MISI— Mistral
MOT— Motorola, Inc
MUL— Mullard, Ltd.
NAE— North American Electronics
NPC— Nucleonic Products Co., Inc.
OHI— Ohio Semiconductor Inc.
OHM— Ohmite Manufacturing Co.
PHI— Philco Corp. Lansdale Div., Semiconductor Operations
PHIN— Philips Gloeilampenfabrieken
PLEB— The Plessey Co.
PSI— Pacific Semiconductors, Inc.
QSC— International Diode Corp.
RADF— La Radiotechnique Div. Tubes Electroniques
RAY— Raytheon Company
RCA— Radio Corporation of America, Semiconductor Div.
RDR— Radio Development and Research Corp.
RHE— Rheem Semiconductor Corp.
ROSG— Dr. Ing. Rudolph Rost
SAR— Sarkes Tarzian, Inc., Rectifier Division
SCN— Semicon, Inc.
SEM— Semi-Elements Inc.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SOIF— Societe Industrial de Liaisons
SONY— Sony Corp.
SSD— Sperry Semiconductor Division
SSP— Solid State Products, Inc.
STC— Shockley Transistor Corp.
STCB— Standard Telephone & Cables, Ltd.
SYL— Sylvania Electric Products, Inc.
SYN— Syntron Co.
TEX— Texas Research Assoc.
TFKG— Telefunken, Ltd.
TI— Texas Instruments Incorporated
TKD— Tekade
TOK— Tokyo Tsushin Kogyo, Ltd.
TRA— Transitron Electronic Corp.
TUN— Tung-Sol Electric, Inc.
TSC— Trans-Sil Corp.
UCI— United Components
USD— United States Dynamics Corp.
UNI— Unitrode Transistor Prods., Corp.
USS— U. S. Semiconductor Products, Inc.
VIC— Vickers Inc.
WEC— Western Electric Co.
WEST— Westinghouse Electric Corp.

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f (mA)	@ E_f (volts)	MAX. D.C. OUTPUT CURRENT[4] (amps)	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b (uA)	@ E_b (volts)	@ T (°C)	MFR. (See code at start of charts)
8B19P	2	S1	500	355	70A	1.2	70	150C	1.2	15	355	150C	FAN-6
8B20N	2	S1	600	426	70A	1.2	70	150C	1.2	15	426	150C	FAN-6
8B20P	2	S1	600	426	70A	1.2	70	150C	1.2	15	426	150C	FAN-6
9A19N	2	S1	500	355	5.0A	1.2	5.0	150C	1.2	1.0	355	150C	FAN-6
9A19P	2	S1	500	355	5.0A	1.2	5.0	150C	1.2	1.0	355	150C	FAN-6
9A20N	2	S1	600	426	5.0A	1.2	5.0	150C	1.2	1.0	426	150C	FAN-6
9A20P	2	S1	600	426	5.0A	1.2	5.0	150C	1.2	1.0	426	150C	FAN-6
10A11N	2	S1	50	35.5	50A	1.2	50	150C	1.2	5.0	35.5	150C	FAN-6
10A11P	2	S1	50	35.5	50A	1.2	50	150C	1.2	5.0	35.5	150C	FAN-6
10A12N	2	S1	100	71	50A	1.2	50	150C	1.2	5.0	71	150C	FAN-6
10A12P	2	S1	100	71	50A	1.2	50	150C	1.2	5.0	71	150C	FAN-6
10A13N	2	S1	150	106	50A	1.2	50	150C	1.2	5.0	106	150C	FAN-6
10A13P	2	S1	150	106	50A	1.2	50	150C	1.2	5.0	106	150C	FAN-6
10A14N	2	S1	200	142	50A	1.2	50	150C	1.2	5.0	142	150C	FAN-6
10A14P	2	S1	200	142	50A	1.2	50	150C	1.2	5.0	142	150C	FAN-6
10A15N	2	S1	250	177	50A	1.2	50	150C	1.2	5.0	177	150C	FAN-6
10A15P	2	S1	250	177	50A	1.2	50	150C	1.2	5.0	177	150C	FAN-6
10A16N	2	S1	300	212	50A	1.2	50	150C	1.2	5.0	212	150C	FAN-6
10A16P	2	S1	300	212	50A	1.2	50	150C	1.2	5.0	212	150C	FAN-6
10A17N	2	S1	350	247	50A	1.2	50	150C	1.2	5.0	247	150C	FAN-6
1N482C	1	S1	36	36	100	1.0	.20	25		.005	30	25	RHE
1N483C	1	S1	70	70	100	1.0	.20	25		.005	60	25	RHE
1N484C	1	S1	130	130	100	1.0	.20	25		.005	125	25	RHE
1N485C	1	S1	180	180	100	1.0	.20	25		.005	175	25	RHE
1N645B	1	S1	225	225	400	1.0	.15	150		.005	60	25	RHE
1N2616	2	S1	800	800	500	1.1	.75	50	1.1	10	800	25	MOT
1N2617	2	S1	1000	1000	500	1.1	.75	50	1.1	10	1000	25	MOT
4B19N	2	S1	500	355	35A	1.2	35	140C	1.7	10	355	140C	FAN-6
4B19P	2	S1	500	355	35A	1.2	35	140C	1.7	10	355	140C	FAN-6
4B20N	2	S1	600	426	35A	1.2	35	140C	1.7	10	426	140C	FAN-6
4B20P	2	S1	600	426	35A	1.2	35	140C	1.7	10	426	140C	FAN-6
6B19N	2	S1	500	355	20A	1.2	20	150C	1.5	5.0	355	150C	FAN-6
6B19P	2	S1	500	355	20A	1.2	20	150C	1.5	5.0	355	150C	FAN-6
6B20N	2	S1	600	426	20A	1.2	20	150C	1.5	5.0	426	150C	FAN-6
6B20P	2	S1	600	426	20A	1.2	20	150C	1.5	5.0	426	150C	FAN-6
7B19N	2	S1	500	355	12A	1.2	12	150C	1.5	10	355	150C	FAN-6
7B19P	2	S1	500	355	12A	1.2	12	150C	1.5	10	355	150C	FAN-6
7B20N	2	S1	600	426	12A	1.2	12	150C	1.5	10	426	150C	FAN-6
7B20P	2	S1	600	426	12A	1.2	12	150C	1.5	10	426	150C	FAN-6
8B19N	2	S1	500	355	70A	1.2	70	150C	1.2	15	355	150C	FAN-6
10A17P	2	S1	350	247	50A	1.2	50	150C	1.2	5.0	247	150C	FAN-6

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f (mA)	@ E_f (volts)	MAX. D.C. OUTPUT CURRENT[4] (amps)	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b (uA)	@ E_b (volts)	@ T (°C)	MFR. (See code at start of charts)
PS2348	9	S1	1500		200	3.0	1.3	25		6.0	1500	25	PSI
PS2349	9	S1	2000		200	4.0	1.1	25		6.0	2000	25	PSI
PS2350	9	S1	2500		200	4.0	1.1	25		6.0	2500	25	PSI
PS2351	9	S1	3000		200	5.0	.90	25		6.0	3000	25	PSI
PS2352	9	S1	3500		200	7.0	.60	25		3.0	3500	25	PSI
PS2353	9	S1	4000		200	7.0	.60	25		3.0	4000	25	PSI
PS2354	9	S1	4500		200	9.0	.525	25		3.0	4500	25	PSI
PS2355	9	S1	5000		200	9.0	.525	25		3.0	5000	25	PSI
PS2356	9	S1	6000		200	10	.475	25		3.0	6000	25	PSI
PS2357	9	S1	7000		200	12	.425	25		3.0	7000	25	PSI
PS2358	9	S1	8000		200	13	.40	25		3.0	8000	25	PSI
PS2359	9	S1	9000		200	15	.35	25		3.0	9000	25	PSI
PS2360	9	S1	10000		200	16	.325	25		3.0	10000	25	PSI
PS2411	9	S1	50		50	2.0	.20	25		5.0	50	25	PSI
PS2412	9	S1	100		25	2.0	.10	25		5.0	100	25	PSI
PS2413	9	S1	200		5.0	2.0	.04	25		5.0	200	25	PSI
PS2414	9	S1	400		5.0	2.0	.04	25		5.0	400	25	PSI
PS2415	9	S1	600		5.0	2.0	.04	25		5.0	600	25	PSI
PS2416	9	S1	800		5.0	2.0	.04	25		10	800	25	PSI
PS2417	9	S1	1000		5.0	4.0	.04	25		10	1000	25	PSI
PS2418	9	S1	1500		5.0	4.0	.04	25		10	1500	25	PSI
PS2419	9	S1	2000		5.0	4.0	.04	25		10	2000	25	PSI
PS2422	2	S1	2000		5.0	6.0	.05	25		10	2000	25	PSI
PS2423	2	S1	3000		5.0	8.0	.05	25		10	3000	25	PSI
PS2424	2	S1	4000		5.0	10	.05	25		10	4000	25	PSI
PS2425	2	S1	5000		5.0	14	.05	25		10	5000	25	PSI
PS2426	2	S1	6000		5.0	16	.05	25		10	6000	25	PSI
PS2427	2	S1	7000		5.0	18	.05	25		10	7000	25	PSI
PS2428	2	S1	8000		5.0	20	.05	25		10	8000	25	PSI
PS2429	2	S1	9000		5.0	24	.05	25		10	9000	25	PSI
PS2430	2	S1	10000		5.0	26	.05	25		10	10000	25	PSI
SC101	2	S1		50			.20	150C		200	50	150C	ESP
SC102	2	S1		100			.20	150C		200	100	150C	ESP
SC103	2	S1		150			.20	150C		200	150	150C	ESP
SC104	2	S1		200			.20	150C		200	200	150C	ESP
SC105	2	S1		250			.20	150C		200	250	150C	ESP
SC106	2	S1		300			.20	150C		200	300	150C	ESP
SC107	2	S1		350			.20	150C		200	350	150C	ESP
SC108	2	S1		400			.20	150C		200	400	150C	ESP
SC109	2	S1		500			.20	150C		200	600	150C	ESP

15A12P	2	S1	100	71	160A	1.2	160	125C	1.2	40	71	125C	FAN-6
15A13N	2	S1	150	106	160A	1.2	160	125C	1.2	40	106	125C	FAN-6
15A13P	2	S1	150	106	160A	1.2	160	125C	1.2	40	106	125C	FAN-6
15A14N	2	S1	200	142	160A	1.2	160	125C	1.2	40	142	125C	FAN-6
15A14P	2	S1	200	142	160A	1.2	160	125C	1.2	40	142	125C	FAN-6
15A15N	2	S1	250	177	160A	1.2	160	125C	1.2	40	177	125C	FAN-6
15A15P	2	S1	250	177	160A	1.2	160	125C	1.2	40	177	125C	FAN-6
15A16N	2	S1	300	212	160A	1.2	160	125C	1.2	40	212	125C	FAN-6
15A16P	2	S1	300	212	160A	1.2	160	125C	1.2	40	212	125C	FAN-6
15A17N	2	S1	350	247	160A	1.2	160	125C	1.2	40	247	125C	FAN-6
15A17P	2	S1	350	247	160A	1.2	160	125C	1.2	40	247	125C	FAN-6
15A18N	2	S1	400	284	160A	1.2	160	125C	1.2	40	284	125C	FAN-6
15A18P	2	S1	400	284	160A	1.2	160	125C	1.2	40	284	125C	FAN-6
15A19N	2	S1	500	355	160A	1.2	160	125C	1.2	40	355	125C	FAN-6
15A19P	2	S1	500	355	160A	1.2	160	125C	1.2	40	355	125C	FAN-6
15A20N	2	S1	600	426	160A	1.2	160	125C	1.2	40	426	125C	FAN-6
15A20P	2	S1	600	426	160A	1.2	160	125C	1.2	40	426	125C	FAN-6
16A11N	2	S1	50	35.5	240A	1.2	240	125C	1.2	50	35.5	125C	FAN-6
16A11P	2	S1	50	35.5	240A	1.2	240	125C	1.2	50	35.5	125C	FAN-6
16A12N	2	S1	100	71	240A	1.2	240	125C	1.2	50	71	125C	FAN-6
16A12P	2	S1	100	71	240A	1.2	240	125C	1.2	50	71	125C	FAN-7
16A13N	2	S1	150	106	240A	1.2	240	125C	1.2	50	106	125C	FAN-6
16A13P	2	S1	150	106	240A	1.2	240	125C	1.2	50	106	125C	FAN-6
16A14N	2	S1	200	142	240A	1.2	240	125C	1.2	50	142	125C	FAN-6
16A14P	2	S1	200	142	240A	1.2	240	125C	1.2	50	142	125C	FAN-6
16A15N	2	S1	250	177	240A	1.2	240	125C	1.2	50	177	125C	FAN-6
16A15P	2	S1	250	177	240A	1.2	240	125C	1.2	50	177	125C	FAN-6.
16A16N	2	S1	300	212	240A	1.2	240	125C	1.2	50	212	125C	FAN-6
16A16P	2	S1	300	212	240A	1.2	240	125C	1.2	50	212	125C	FAN-6
16A17N	2	S1	350	247	240A	1.2	240	125C	1.2	50	247	125C	FAN-6
16A17P	2	S1	350	247	240A	1.2	240	125C	1.2	50	247	125C	FAN-6
16A18N	2	S1	400	284	240A	1.2	240	125C	1.2	50	284	125C	FAN-6
16A18P	2	S1	400	284	240A	1.2	240	125C	1.2	50	284	125C	FAN-6
16A19N	2	S1	500	355	240A	1.2	240	125C	1.2	50	355	125C	FAN-6
16A19P	2	S1	500	355	240A	1.2	240	125C	1.2	50	355	125C	FAN-6
16A20N	2	S1	600	426	240A	1.2	240	125C	1.2	50	426	125C	FAN-6
16A20P	2	S1	600	426	240A	1.2	240	125C	1.2	50	426	125C	FAN-6
B284	2	S1	300	300			10	150	1.2		300	150	BRI
B285	2	S1	400	400			10	150	1.2		400	150	BRI
B286	2	S1	500	500			10	150	1.2		500	150	BRI
B287	2	S1	600	600			10	150	1.2		600	150	BRI
B288	2	S1	800	800			10	150	1.2		800	150	BRI
B289	2	S1	1000	1000			10	150	1.2		1000	150	BRI
B290	2	S1	1200	1200			10	150	1.2		1200	150	BRI
B291	2	S1	300	300			.50	100	1.2		300	100	BRI
B292	2	S1	400	400			.50	100	1.2		400	100	BRI
B293	2	S1	500	500			.50	100	1.2		500	100	BRI
B294	2	S1	600	600			.50	100	1.2		600	100	BRI
B295	2	S1	800	800			.50	100	1.2		800	100	BRI
B2200	2	S1	2200	2200			.40	25	2.0		2200	25	BRI
B2201	2	S1	2200	2200			1.0	25	2.0		2200	25	BRI
B2202	2	S1	2200	2200			5.0	25	2.0		2200	25	BRI
CC5-15	1	S1	15				.50	25	1.0	10	15	25	CON
CC5-30	1	S1	30				.50	25	1.0	10	30	25	CON
CC5-50	1	S1	50				.50	25	1.0	10	50	25	CON
CC5-75	1	S1	75				.50	25	1.0	15	75	25	CON
CC5-100	1	S1	100				.50	25	1.0	20	100	25	CON
CC5-150	1	S1	150				.50	25	1.0	20	150	25	CON
CC5-200	1	S1	200				.50	25	1.0	20	200	25	CON
CC5-250	1	S1	250				.50	25	1.0	25	250	25	CON
CC5-300	1	S1	300				.50	25	1.0	25	300	25	CON
CC5-500	1	S1	500				.50	25	1.0	25	500	25	CON
PS1441	2	S1	1500		200	4.0	.50	25		1.0	1500	25	PSI
PS1442	2	S1	2000		200	4.0	.50	25		1.0	2000	25	PSI
PS1443	2	S1	3000		200	8.0	.40	25		1.0	3000	25	PSI
PS1444	2	S1	4000		200	8.0	.40	25		1.0	4000	25	PSI
PS1445	2	S1	5000		200	12	.30	25		1.0	5000	25	PSI
PS1446	2	S1	6000		200	12	.30	25		1.0	6000	25	PSI
PS1447	2	S1	7000		200	17	.30	25		1.0	7000	25	PSI
PS1448	2	S1	8000		200	17	.30	25		1.0	8000	25	PSI
PS1449	2	S1	9000		200	22	.25	25		1.0	9000	25	PSI
PS1450	2	S1	10000		200	22	.25	25		1.0	10000	25	PSI
PS1451	2	S1	11000		200	32	.25	25		1.0	11000	25	PSI
PS1452	2	S1	12000		200	34	.22	25		1.0	12000	25	PSI
PS1453	2	S1	13000		200	34	.22	25		1.0	13000	25	PSI
PS1454	2	S1	14000		200	38	.20	25		1.0	14000	25	PSI
PS1455	2	S1	15000		200	38	.20	25		1.0	15000	25	PSI
PS1456	2	S1	16000		200	38	.20	25		1.0	16000	25	PSI
PS1457	2	S1	17000		200	38	.20	25		1.0	17000	25	PSI
PS1458	2	S1	18000		200	38	.20	25		1.0	18000	25	PSI
PS1459	2	S1	19000		200	38	.20	25		1.0	19000	25	PSI
PS1460	2	S1	20000		200	38	.20	25		1.0	20000	25	PSI
PS2345	9	S1	300		200	1.0	1.5	25		6.0	300	25	PSI
PS2346	9	S1	600		200	1.0	1.5	25		6.0	600	25	PSI
PS2347	9	S1	1000		200	2.0	1.5	25		6.0	1000	25	PSI

5 - Controlled Rectifier
6 - Dual Rectifier
7 - Controlled Forward Conductance

OTHER
4 - For half wave resistance lead average over 1 cycle

REVERSE CURRENT
∅ - Dynamic

MFR
6 - Available in Stack form from Mfr.

∅ - Insulated Base
△ - Direct Tube Replacement
† - Pair
\# - Forced Air Cooling

FOLLOWING ANY TEMPERATURE READING
A - Ambient
C - Case
J - Junction
S - Storage
△ - Inlet temperature of coolant

SWITCHING DIODES

TYPE NO.	MAT	PIV	MAX. CONT. REV. WORK VOLT.	Min. Forward Current @ 25°C		MAX. REVERSE CURRENT @ 25°C		Recovery Characteristics				MFR. (See code at start of charts)
				I_f	@ E_f	I_b	@ E_b	TEST CONDITIONS Fwd. I_f	Rev. to E_b	$Z_{rec.}$	@ time (t)	
		(volts)	(volts)	(mA)	(volts)	(μa)	(volts)	(ma)	(volts)	(K ohms)	(usec)	
1N251A	S1	125	125	5.0	1.0	.10	10	5.0	10	20	.15	RHE
1N252A	S1	125	125	10	1.0	.10	10	5.0	10	40	.15	RHE
1N625A	S1	30	30	10	1.5	.10	20	30	35	400	.50	RHE
1N626A	S1	50	50	10	1.5	.10	35	30	35	400	.50	RHE
1N627A	S1	100	100	10	1.5	.10	75	30	35	400	.50	RHE
1N628A	S1	150	150	10	1.5	.10	125	30	35	400	.50	RHE
1N629A	S1	200	200	10	1.5	.10	175	30	35	400	.50	RHE
1N658A	S1	100	100	100	1.0	.025	50	5.0	40	80	.30	RHE
1N659A	S1	50	50	10	1.0	.025	50	30	35	400	.30	RHE
1N660A	S1	100	100	10	1.0	.025	100	30	35	400	.30	RHE
1N661A	S1	200	200	10	1.0	.025	200	30	35	400	.30	RHE
PD301	S1	40		10	1.0	.025	20	10	6.0		.004	PSI
PD302	S1	40		10	1.0	.10	20	10	6.0		.004	PSI
PD303	S1	40		10	1.0	.10	30	10	6.0		.004	PSI
PD304	S1	40		10	1.0	.10	40	10	6.0		.004	PSI
PD305	S1	80		10	1.0	.025	20	10	6.0		.004	PSI
PD306	S1	40		10	1.0	.025	20	10	6.0		.004	PSI
PD307	S1	40		10	1.0	.10	20	10	6.0		.004	PSI
PD308	S1	40		10	1.0	.10	30	10	6.0		.004	PSI
PD309	S1	40		10	1.0	.10	40	10	6.0		.004	PSI
PD310	S1	80		10	1.0	.025	20	10	6.0		.004	PSI
PD311	S1	60		10	1.0	.10	50	10	6.0		.002	PSI

VOLTAGE VARIABLE CAPACITOR DIODES

TYPE NO.	CAPACITANCE C @ Eb		PIV	Q @ FREQ.		MFR.
	(uuf)	(volts)		Min. Q	(mc)	
PC132	10	4.0	25	50	50	PSI
PC133	22	4.0	25	50	50	PSI
PC134	47	4.0	25	50	50	PSI
PC135	10	4.0	50	150	50	PSI
PC136	22	4.0	50	125	50	PSI
PC137	47	4.0	50	100	50	PSI

UNDER TYPE NO.
∅ - Ceramic Crystal Cartridge
△ - Double Ended Varactor
* - Sub Miniature Ceramic
† - Sub Miniature Glass
∅ - Miniature Pill Varactor

UNDER Q
∅ - Typical

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z @ I_z (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EF-FICIENT %/°C	MFR. (See code at start of chart)
1N821A	5.9	6.5	7.5	10	7.5	400	.01	MOT
1N823A	5.9	6.5	7.5	10	7.5	400	.005	MOT
1N825A	5.9	6.5	7.5	10	7.5	400	.002	MOT
1N827A	5.9	6.5	7.5	10	7.5	400	.001	MOT
1N3154	8.0	8.8	10	15	10	400	.01	MOT
1N3154A	8.0	8.8	10	15	10	400	.01	MOT
1N3155	8.0	8.8	10	15	10	400	.005	MOT
1N3155A	8.0	8.8	10	15	10	400	.005	MOT
1N3156	8.0	8.8	10	15	10	400	.002	MOT
1N3156A	8.0	8.8	10	15	10	400	.002	MOT
1N3157	8.0	8.8	10	15	10	400	.001	MOT
2N1695 †	9.5	10.5	5.0			300	.005	ITC
2N1696 †	9.5	10.5	5.0			300	.002	ITC
2N1697 †	8.5	9.8	5.0			300	.02	ITC
2N1698 †	9.5	11	5.0			300	.02	ITC
CC5D1.5	1.35	1.65	50	10	50			CON
CC5D1.8	1.63	1.98	50	10	50			CON
CC5D2.2	1.97	2.42	50	10	50			CON
CC5D2.7	2.42	2.96	50	20	50			CON
CC5D3.3	2.96	3.62	30	20	30			CON
CC5D3.9	3.51	4.28	30	20	30			CON
CC5D4.7	4.23	5.16	30	20	30			CON
CC5D5.6	5.04	6.15	20	20	20			CON
CC5D6.8	6.12	7.46	20	20	20			CON
CC5D8.2	7.38	9.02	10	15	10			CON
CC5D10	9.0	11.1	10	15	10			CON
CC5D12	11	13.5	10	15	10			CON
CC5D15	13.4	16.5	10	25	10			CON
CC5D18	16.3	19.8	10	35	10			CON
CC5D22	19.7	24.2	3.0	50	3.0			CON
CC5D27	24.1	29.6	3.0	60	3.0			CON
CC5D33	29.5	36.2	3.0	80	3.0			CON
MRA1 †	7.5	8.5	5.0			300	.005	ITC
MRA1A †	7.5	8.5	5.0			300	.002	ITC
MRA2 †	8.5	9.5	5.0			300	.005	ITC
MRA2A †	8.5	9.5	5.0			300	.002	ITC
MRA4 †	10.5	11.5	5.0			300	.005	ITC
MRA4A †	10.5	11.5	5.0			300	.002	ITC
MRA5 †	11.5	12.5	5.0			300	.005	ITC
MRA5A †	11.5	12.5	5.0			300	.002	ITC
PS1421	3.14	3.47	20	30	20	2000	.21	PSI
PS1421A	3.23	3.37	20	30	20	2000	.21	PSI
PS1422	3.42	3.78	20	21	20	2000	.21	PSI
PS1422A	3.53	3.67	20	21	20	2000	.21	PSI
PS1423	3.80	4.20	20	32	20	2000	.21	PSI
PS1423A	3.92	4.08	20	32	20	2000	.21	PSI
PS1424	4.18	4.62	20	24	20	2000	.21	PSI
PS1424A	4.31	4.49	20	24	20	2000	.21	PSI
PS1425	4.56	5.04	20	39	20	2000	.21	PSI
PS1425A	4.70	4.90	20	39	20	2000	.21	PSI
PS1426	4.94	5.46	20	29	20	2000	.21	PSI
PS1426A	5.10	5.30	20	29	20	2000	.21	PSI
PS1501	8.0	8.8	10	15	10		.002	PSI
PS1501A	8.0	8.8	10	15	10		.001	PSI
PS1502	16	17.6	10	30	10		.002	PSI
PS1502A	16	17.6	10	30	10		.001	PSI
PS1503	24	26.4	10	45	10		.002	PSI
PS1503A	24	26.4	10	45	10		.001	PSI
PS1504	32	35.2	10	60	10		.002	PSI
PS1504A	32	35.2	10	60	10		.001	PSI
PS1505	40	44	10	75	10		.002	PSI
PS1505A	40	44	10	75	10		.001	PSI
PS1506	48	52.8	10	90	10		.002	PSI
PS1506A	48	52.8	10	90	10		.001	PSI
PS1507	56	61.6	10	105	10		.002	PSI
PS1507A	56	61.6	10	105	10		.001	PSI
PS1508	64	70.4	10	120	10		.002	PSI
PS1508A	64	70.4	10	120	10		.001	PSI
PS1509	72	79.2	10	135	10		.002	PSI
PS1509A	72	79.2	10	135	10		.001	PSI
PS1510	80	88	10	150	10		.002	PSI
PS1510A	80	88	10	150	10		.001	PSI
SS9.1Z	8.2	10	30	5.0	30	600		ESP
SS10Z	9.0	11	30	5.5	30	600		ESP
SS11Z	9.9	12.1	30	6.0	30	600		ESP

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z @ I_z (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EF-FICIENT %/°C	MFR. (See code at start of chart)
SS20Z	18	22	10	16	10	600		ESP
SS22Z	19.8	24.2	10	20	10	600		ESP
SS24Z	21.6	26.4	10	23	10	600		ESP
SS27Z	24.3	29.7	10	25	10	600		ESP
SS30Z	27	33	10	30	10	600		ESP
SS33Z	29.7	36.3	10	37	10	600		ESP
SS36Z	32.4	39.7	10	49	10	600		ESP
SS39Z	35.1	42.9	10	57	10	600		ESP
SS43Z	38.7	47.3	10	69	10	600		ESP
SS47Z	42.3	51.7	10	74	10	600		ESP
SS51Z	45.9	56.1	10	91	10	600		ESP
SS56Z	50.4	61.6	10	108	10	600		ESP
SS62Z	55.8	68.2	3.0	135	3.0	600		ESP
SS68Z	61.2	74.8	3.0	155	3.0	600		ESP
SS75Z	67.5	82.5	3.0	180	3.0	600		ESP
SS82Z	73.8	90.2	3.0	215	3.0	600		ESP
SS91Z	81.9	100	3.0	260	3.0	600		ESP
SS100Z	90	110	3.0	330	3.0	600		ESP
SS110Z	99	121	3.0	400	3.0	600		ESP
SS120Z	108	132	3.0	470	3.0	600		ESP
SS130Z	117	143	3.0	550	3.0	600		ESP
SS150Z	135	165	3.0	730	3.0	600		ESP
SS160Z	144	176	3.0	820	3.0	600		ESP
SS180Z	162	198	3.0	1050	3.0	600		ESP
SS200Z	180	220	3.0	1200	3.0	600		ESP
SZ10C	9.0	11	20	20	20	1500	.06	GECB
SZ12C	10.8	13.4	20	30	20	1500	.07	GECB
SZ15C	13.2	16.5	20	40	20	1500	.07	GECB
SZ18C	16.2	19.9	20	65	20	1500	.08	GECB
SZ22C	19.7	24.4	20	90	20	1500	.08	GECB
SZ27C	24.2	29.8	20	120	20	1500	.09	GECB
SZ33C	29.2	36.3	20	150	20	1500	.09	GECB
SZ56A	4.9	6.2	20	15	20	1500	.02	GECB
SZ68A	6.1	7.5	20	10	20	1500	.04	GECB
SZ82A	7.4	9.1	20	15	20	1500	.05	GECB
XMRA2 †	8.5	9.8	5.0			300	.05	ITC
XMRA3 †	9.5	11	5.0			300	.05	ITC
XMRA4 †	10.5	12	5.0			300	.05	ITC
XMRA4A †	10.5	12	5.0			300	.02	ITC

UNDER TYPE NO.
⊘ - Revised Specifications
Ø - Double Anode Type
* - Developmental Type
Δ - Also available with ±5 per cent tolerance
† - Reference Amplifier
\# - Available with reverse polarity

PREVIOUSLY REGISTERED NEWLY ANNOUNCED DIODES

BENDIX:
1N1124 thru 1N1128, 1N1199 thru 1N1206, 1N1341 thru 1N1348, 1N1581 thru 1N1587, 1N2491 thru 1N2497

CBS ELECTRONICS:
1N456, 1N457, 1N458, 1N459

COLUMBUS ELECTRONICS:
1N1139, 1N1140, 1N1141, 1N1142, 1N1143, 1N1143A, 1N1144, 1N1145, 1N1146, 1N1147, 1N1148, 1N1149

COMPUTER DIODE:
1N456 thru 1N459, 1N456A thru 1N459A, 1N461 thru 1N464, 1N461A thru 1N464A, 1N482 thru 1N488, 1N482A thru 1N488A, 1N482B thru 1N486B, 1N625 thru 1N629, 1N643, 1N643A, 1N643B, 1N645 thru 1N649, 1N659 thru 1N663, 1N662A, 1N663A, 1N690 thru 1N693, 1N778 thru 1N809, 1N837 thru 1N845, 1N837A, 1N891, 1N892, 1N893, 1N934

DICKSON ELECTRONICS:
1N253 thru 1N256, 1N1115 thru 1N1120, 1N1805 thru 1N1815, 1N1351 thru 1N1375, 1N1767 thru 1N1802

HOFFMAN SEMICONDUCTOR:
1N643, 1N645 thru 1N649, 1N662, 1N663, 1N761 thru 1N769, 1N823, 1N824, 1N957A thru 1N992A, 1N957B thru 1N992B, 1N957RA thru 1N992RA, 1N957RB thru 1N992RB, 1N2808A thru 1N2846A, 1N2808B thru 1N2846B, 1N2808RA thru 1N2846RA, 1N2808RB thru 1N2846RB, 1N2970A thru 1N3051A, 1N2970B thru 1N3051B, 1N2970RA thru 1N3051RA, 1N2970RB thru 1N3051RB

HUGHES PRODUCTS:
1N48, 1N268, 1N288, 1N294, 1N297

KEMTRON ELECTRON:
1N23F, 1N23RF, 1N25B, 1N25RB, 1N1611A, 1N2771

MOTOROLA SEMICONDUCTOR:
1N332 thru 1N337, 1N339 thru 1N346, 1N348, 1N349, 1N440 thru [illegible]

Industry News . . .

CONFERENCE CALENDAR

The Following April 1961 Meetings Are Scheduled:

April 4-6 Intl. Symp. on Electromagnetics & Fluid Dynamics of Gaseous Plasma, Engineering Societies Auditorium, 33 W. 39th St., NYC. Sponsored by PGED, MTT, NS, PIB, IAS, Dept. of Defense. For Information: Symposium Committee, Polytechnic Inst. of Bklyn., 55 Johnson St., Bklyn 1, N. Y.

April 5-7 Institute of Environmental Sciences Annual Technical Meeting & Equipment Exposition, Park Sheraton Hotel, Wash., D. C. Sponsored by Inst. of Env. Sciences, POB 191, Mt. Prospect, Ill. For Information: A. S. Jenkins, Emerson Res. Labs, 1140 East-West Highway, Silver Spring, Md.

April 5-7 Symposium on Materials and Electron Device Processing, Benjamin Franklin Hotel, Phila., Pa. Sponsored by Amer. Society for Testing Materials. For Information: ASTM, 1916 Race St., Phila 3, Pa.

April 11-13 Conference on the Ultrapurification of Semiconductor Materials, New England Mutual Hall, Boston, Mass. Sponsored by the Electronics Research Directorate, Air Force Cambridge Res. Labs. For Information: Helen Turin, Conference Secy., CRREP, Electronics Res. Directorate, AF Cambridge Res. Labs, AF Res. Div., L. G. Hanscom Field, Bedford, Mass.

April 19-21 SWIRECO (S. W. IRE Conference & Elec. Show), Dallas Memorial Aud. & Baker Hotel, Dallas, Tex. Sponsored by Region 6. For Information: Dr. L. D. Strom, Texas Instruments Inc., 6000 Lemmon Ave., Dallas, Tex.

April 19-21 Great Lakes District Meeting, AIEE, Pick-Nicollet Hotel, Minneapolis, Minn.

April 24-47 American Physical Society Meeting, Park Sheraton Hotel, Wash., D. C. Sponsored by AIS.

April 26-27 High Temperature Materials Conference, Hotel Pick-Carter, Cleveland. Sponsored by The Metallurgical Society of AIME. For Information: AIME, 29 W. 39th St., N. Y. 18, N. Y.

April 26-28 IRE 7th Regional Conference & Trade Show, Westward Ho Hotel, Phoenix, Ariz. Sponsored by Region 7. For Information: H. W. Welch, Jr., Motorola, Inc., POB 1417, Scottsdale, Ariz.

April 30-May 4 Electrochemical Society Meeting, incorporating 9th Annual Semiconductor Symposium, Claypool Hotel, Indianapolis, Ind. For Information: Electrochemical Society, 1860 Broadway, New York 23, N. Y.

RESEARCH AND DEVELOPMENT

The nation's electrical engineers were recently given evaluations of the efficiency of thermoelectric generators, a possible source of power in space vehicles and ships. In space power systems maximum efficiency of thermoelectricity generators would be somewhat below 6% and for marine applications it would be about 15%, a solid state device symposium was told during the Winter General Meeting of the American Institute of Electrical Engineers. The evaluations were made by B. Evans, of the Martin Company, Denver, Col., and Dr. E. T. B. Gross of the Illinois Institute of Technology, Chicago, in a paper, "Evaluation of Thermoelectric Energy Conversion."

"For a space power system a present practical value for hot junction temperature is about 1100°F, and for cold junction about 700°F." Therefore, "the maximum efficiency equals 400/1560, equals 0.257," they pointed out, adding that the maximum efficiency is "somewhat below 6% for ZT (the figure of merit times the hot junction absolute temperature in degree Kelvin), equals 1.5. A ZT value between 1 and 1.3 would be a more realistic value," reducing the maximum efficiency to about 5%.

For marine application, with sea water cooling, "we may select 1100°F again for the hot junction, but can reduce the cold junction temperature to about 80°F", therefore the Carnot efficiency equals 1020/1560, equals 0.654. The maximum thermoelectric conversion efficiency equals 23% for ZT somewhat below 1.5, leading to maximum efficiency of 15%.

The authors warned, however, that the efficiencies given were obtained under "ideal conditions of operation and the values are far better than could be achieved on practical converters." To get realistic values a "degrading" factor should be applied, including various heat losses, temperature drops between heat source and hot junction and between cold junction and heat sink, changes in material at a junction, contact resistances and circulating current. "A rough estimate suggests that 60% may be a good value for this degrading factor. Accordingly the overall efficiencies for the examples reduce to 3% for the space power system, and to 9% for the marine application. If the thermoelectric converter is designed for maximum efficiency, these values would be further reduced. . . ."

(*Continued on page* 79)

Market News . . .

Sales

The Electronics Division, Business and Defense Services Administration, U. S. Department of Commerce has reported that for the second successive quarter, output of semiconductor devices (transistors, diodes and rectifiers, and related devices) declined in value. This decline was entirely due to lower prices, since unit output continued to rise. The following table shows the estimated total industry shipments during the third quarter of 1960.

Category	Quantity (in thousands of units)			Value (in thousands of dollars)		
	Total	Military	Non-military	Total	Military	Non-mil
SEMICONDUCTOR DEVICES	81.925	22.434	59,491	126,583	60,796	65,787
Diodes, rectifiers and related devices ..	52,138	17.346	34,792	56,149	27,174	28,975
Germanium diodes and rectifiers	24.816	7,567	17,249	11,721	4,914	6,807
0-30 ma	13.273	3.953	9,320	5,686	2,372	3,314
31-100 ma	9,603	2,985	6,618	4,541	2,043	2,498
Over 100 ma	1.940	629	1.311	1.494	499	995
Silicon diodes and rectifiers	20,850	8,565	12,285	31,684	16,654	15,030
0-30 ma	4,785	3,168	1,617	7,398	5,374	2,024
31-100 ma	3,918	2,027	1,891	6,566	4,148	2,418
101-550 ma	6,132	1,775	4,357	7,286	3,193	4,093
551 ma—3 amps ..	3,711	1,329	2,382	4,857	1,897	2,960
Over 3 amps—35 amps	2,181	216	1,965	3,665	1,145	2,520
Over 35 amps	123	50	73	1,912	897	1,015
Zener diodes	1,556	695	861	6.600	2,928	3,672
Microwave diodes .	228	228	[1]	1,125	1,125	[1]
Infra-red and other semiconductor photo cells, except solar cells	67	10	57	565	315	250
Other[2]	4,621	281	4,340	4,454	1,238	3,216
Transistors	29.787	5,088	24,699	70,434	33,622	36,812
Germanium	26.242	3,146	23,096	42,838	14,022	28,816
0-125 mw	9,352	1,424	7,928	14,654	5,806	8,848
126-999 mw	13,608	1,350	12,258	19,850	5,605	14.245
1 watt and over ..	3.282	372	2,910	8,334	2,611	5,723
Silicon	3,545	1,942	1,603	27,596	19,600	7,996

[1] Non-military shipments of microwave diodes were combined with military shipments to avoid disclosure of proprietary information.
[2] Includes diodes and rectifiers made from materials other than silicon and germanium, tunnel diodes, controlled rectifiers, solar cells, and other special semiconductor devices which must be combined to avoid disclosure of proprietary information.

According to monthly figures released by the Electronic Industries Association, factory sales of transistors totaled 12,149,077 during November 1960, a decline of 19,555 units under the total for the previous month. Revenue accrued from sales dropped to $25,372,480, a total of $572,715 below that for October. Year-to-date totals for the 11-month period stayed substantially ahead of last year's totals for both sales and revenue. EIA's latest transistor statistics are shown below:

	Factory Sales (Units)	*Factory Sales (Dollars)*
November	12,149,077	$25,372,480
October	12,168,632	25,945,195
September	12,973,792	28,442,229
August	9,732,993	22,739,969
July	7,070,884	18,083,802
June	10,392,412	27,341,733
May	9,046,237	24,146,373
April	9,891,236	23,198,576
March	12,021,506	28,700,129
February	9,527,662	24,831,570
January	9,606,630	24,714,580
Jan.-Nov. '60	114,581,061	273,516,636
Jan.-Nov. '59	74,467,926	199,189,791

The Bureau of Mines has estimated domestic production of high-purity silicon in 1960 at 90,000 pounds, compared with 73,000 pounds in 1959. The total value of single and polycrystal silicon produced in 1960 was also estimated at $28 million, as against $13.6 million in 1959. Most single-crystal silicon was sold for about $750 a pound while polycrystal varied from $330 to $200 a pound.

The output of semiconductor devices as compared with electron tubes has grown from 2.9% in 1952 to 63.3% in 1960 according to the preliminary figures for last year as given by the Marketing Data Department of the Electronics Division of the U. S. Department of Commerce.

Electronics Output
(In millions of dollars)

Year	Electron tubes	Semi-conductor devices
1960	845p	535p
1959	865	395
1958	790	210
1957	820	150
1956	790	90
1955	770	40
1954	690	25
1953	734	25
1952	690	20

Domestic exports of semiconductor devices was estimated to be $16 million for 1960. This represents an increase of 73.8% over the $9.148 million figure of 1959. The department also states in its latest release that the number of firms in 1959 actively engaged in manufacturing transistors was 30 while 45 were manufacturing diodes and rectifiers.

The Japanese Ministry of Finance has reported exports of transistors to the United States for the third quarter has declined from $624,000 in 1959 to $190,000 in 1960. Exports of transistors and other semiconductor devices for 1958, 1959 and January-September 1959 and 1960 are:

Product	Quantity (in thousands of units)				Value (in thousands of dollars)			
			Jan.-Sept.				Jan.-Sept.	
	1958	1959	1959	1960	1958	1959	1959	1960
Transistors	11	2,393	1,828	1,235	7	1,581	1,145	821
Other semiconductor devices	—	597	529	123	—	92	81	22

General Electric's Semiconductor Products department has established a southeastern sales region to serve 10 states and the District of Columbia. Its headquarters will be on 14th Street N. W. Washington, D.C.

Raytheon Co. has set up headquarters in Zug, Switzerland for its European manufacturing sales and technical service organization. The firm will have representatives in the six-nation European Common Market and the seven-nation European Free Trade Association.

Japan imported approximately 1.2 metric tons of silicon single crystals during 1960, compared with 1.3 metric tons the previous year. Imports this year are expected to be reduced substantially as six Japanese silicon fabricators are stepping up their production capacities.

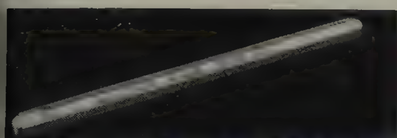
Wallson Associates, Inc., Elizabeth, New Jersey, announces the appointment of L&M Associates, Saddle Brook, New Jersey, as sales representative for its line of semiconductor test equipment. They will cover the areas of New Jersey, southern New York, eastern Pennsylvania and western Connecticut.

Rheem Semiconductor Corp. has recently received military qualification on four of their general-purpose, medium-power transistors. These silicon mesa transistors are: 2N497, 2N498, 2N656, and 2N657.

(Continued on page 77)

New Products

ew Solder



A new solder for use on printed circuit ›ards and dip soldering leads of diodes ıd transistors is being intrdouced by lpha Metals, Inc., at their IRE Show ooth 4328. Made by a special process, lpha AAA Solder reduces inherent ıclusions, improves wetting, produces righter, oxide-free soldering connections ıd minimizes drossing. This last char- cteristic gives the solder bath longer life. : is said to provide more usage per ound, and is available from stock in ıost of the common tin-lead alloys.

Circle 159 on Reader Service Card

ransparent Silicone Resin Encapsulant

A new flexible encapsulating material, ylgard 182 Resin, that permits visual in- pection of circuits and components vithin potted, embedded or encapsulated ssemblies, has been developed by Dow Corning Corporation. At 150°C, it cures n 15 minutes; at 65°C, four hours; at 5°C, three days. Neither the resin not ts curing agent is toxic to the skin. No oxic fumes are given off during mixing r curing.

Circle 105 on Reader Service Card

Jltrasonic Cleaner

L & R Manufacturing Company has announced a low-cost ultrasonic cleaner, the Maxson, which has a full 1¼ quart capacity and features a new built-in electronic circuit that transmits "peak power" directly from the transducer to the cleaning tank. It is designed to clean a large volume of large pieces faster, more efficiently, more economically. The unit is ready for immediate plug-in operation in a space just 8" by 6". Power output is 45 watts; power consumed is 140 watts; operating frequency is 70-80 KC.

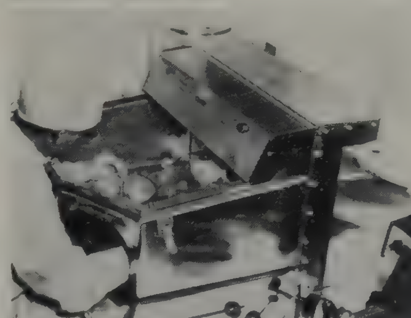
Circle 104 on Reader Service Card

Epitaxial Silicon Transistors

Texas Instruments Incorporated has announced the commercial availability of two ultra-fast silicon switching transistors manufactured by the new epitaxial process. While the new devices are expected to find their greatest immediate application in electronic computers, TI said their potential range of usage permits them to be classified and used also as small-signal general purpose transistors. Operating capability is within a range of −65°C to +175°C.

Circle 118 on Reader Service Card

Dust-Free Enclosures



The latest S. Blickman, Inc., enclosure in the war against dust excludes particles on the order of 1 micron (1,000th of a millimeter) or smaller. It is completely fabricated of all-welded stainless steel with no crevices. The working surface is low enough to permit comfortable use of a microscope by a seated technician, with the microscope and the operator's head outside the enclosure. The work area within the enclosure is large enough to accommodate a dozen components for assembly, and there is work space outside the enclosure as well.

Circle 103 on Reader Service Card

In-Circuit Transistor Tester

A new transistor tester claimed to be capable of measuring *A-C* Beta with an accuracy of ±5% has been introduced by Hickok Electrical Instrument Company. Utilizing an *A-C* bridge principle, with the transistor input elements as one arm of the bridge, the total impedance is nulled. With circuit impedances as low as 150 ohms, it is claimed that this effectively removes these elements from the circuit as a factor in the Beta measurement.

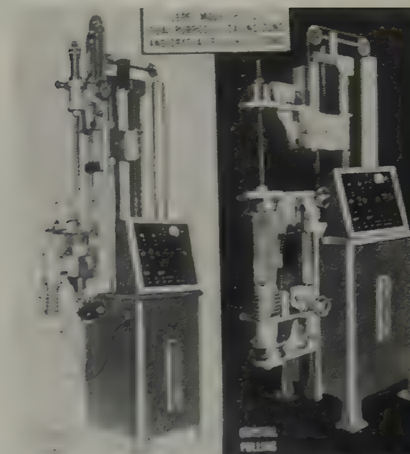
Circle 135 on Reader Service Card

Microwave Varactor Diodes

Microwave silicon varactor diodes, with cutoff frequencies as high as 150 kmc at minus 45 volts breakdown voltage, have been developed through epitaxial techniques by Sylvania. The high Q, high breakdown voltage diodes exhibit frequencies as high as 100 kmc and capacitance values as low as 0.15 pf at minus 6 volts. As harmonic generators, the new devices feature exceptional power handling capabilities, according to the company.

Circle 123 on Reader Service Card

Floating Zone And Crystal Pulling Fixture



Lepel High Frequency Laboratories has developed a dual purpose fixture for crystal pulling and floating zone applications for use with a high frequency induction heating generator. The floating zone method has been used extensively for zone refining and for growing crystals of high purity silicon for semiconductor devices. In the crystal pulling method, single crystals of various materials, especially germanium, have been successfully grown. The basic requirements of these operations are a means of heating the material to a liquid state and maintaining the temperature slightly above the melting point, a desired atmosphere surrounding the melt and the growing crystal, a controlled traversing mechanism for moving the induction coil or the material being processed. All these features and more are incorporated in Model HCP-D.

Circle 128 on Reader Service Card

Rectifier Test Set

Dynatran Model 1826 High Voltage Rectifier Test Set is designed to provide an oscilloscope display of the reverse characteristics of high voltage diodes and high power rectifiers. This instrument provides a wide range of reverse voltages up to 5000 volts and reverse currents from less than 1 microampere to 1 ampere. The instrument includes a built-in oscilloscope and test chamber.

Circle 116 on Reader Service Card

High-Speed Diode

Rheem high-frequency silicon diode JAN 1N251 is available per MIL-E-1/1023. Features milli-microsecond switching and low leakage for critical logic, detector and other high frequency applications. It provides 0.15 μsec reverse switching time; 0.1μAdc reverse current @ −10V; 1.0 Vdc forward voltage @ I_F of 5 mA; 150 mW power dissipation and 30 V. reverse voltage.

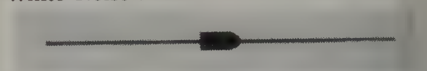
Circle 112 on Reader Service Card

Germanium Alloy Transistors

A new series of *p-n-p* germanium alloy transistors for applications requiring high gain and low noise characteristics has been introduced by GE. 2N1175A has a maximum broad band noise figure of 6-db., measured from 15 cycles per second to one kilocycle, and a typical broad band noise figure of 4-db. 2N1175 and 1175A have minimum collector to base voltage ratings of 35 volts, collector to emitter minimum ratings of 25 volts and minimum emitter to base voltage ratings of 10 volts. They have a typical collector cutoff current of six microamperes with a collector to base voltage of 30 volts. The devices are rated for operation in the minus 65°C to plus 85°C temperature range.

Circle 110 on Reader Service Card

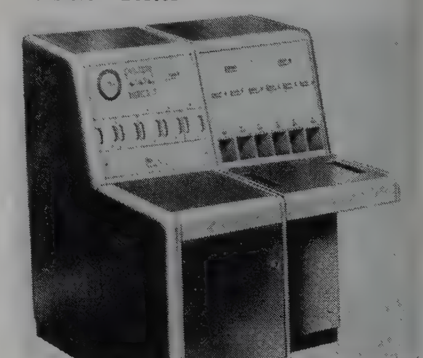
White Noise Diode



A new development in the field of solid state devices, the Sounvister, which, according to the company, is capable of producing random noise across a white noise spectrum was announced by Solitron Devices, Inc. Random noise can be harnessed in selected frequency ranges known as yellow and pink noise bands. A white noise generator into which the 3/8" device has been integrated is capable of producing up to 18 volts output. One of its commercial applications includes use in an instrument used by dentists to eliminate pain in the drilling or extraction of teeth. Other applications of white noise may eventually eliminate the use of anesthesia in medicine entirely. The device is expected to accelerate military and commercial R & D in the sound field.

Circle 138 on Reader Service Card

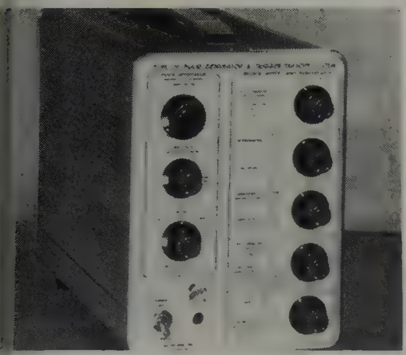
Transistor Tester



A Semi-automatic Component Tester (SACT) for ultra-reliable testing and classification of transistors according to user specifications at speeds of 30 to 60 tests per second and resolution below a fraction of a microampere has been developed by Monitor Systems, Inc., Div. of Epsco, Inc. Adaptable to both manual and mechanized operations.

Circle 129 on Reader Service Card

se Generator & gger Takeoff System



Tektronix Type 110 Pulse Generator d Trigger Takeoff System facilitates easurement of amplifier linearity, and gger sensitivity to amplitude or pulse-dth changes. Pulse risetime is less than 5 nano-second. Repetition rate nomi-lly 720 pulses/second. Output imped-ce is 50 ohms. The system can generate ternate pulses of different lengths, am-itudes, and polarity. An independent igger Takeoff System provides stable iggering over a wide range of signal nplitudes.

Circle 101 on Reader Service Card

irconia Refractory

Fused stabilized zirconia refractory, eveloped by Norton Company in 1951, as recently been placed in its first com-ercial application as a refractory for urnace construction. A furnace designed o operate continuously at elevated emperatures in the vicinity of 2200°C 3992°F) has been built by C M Manu-acturing and Machine Company. The efractory for lining the hot-zone is used stabilized zirconia manufactured y Norton Company. The heating ele-nents are specially selected and ma-hined tungsten rods. The furnace can e operated with hydrogen or other re-lucing or inert atmospheres compatible vith the furnace materials.

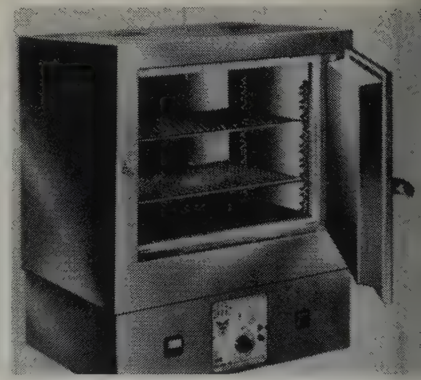
Circle 139 on Reader Service Card

Semiconductor Alloy Kit

A semiconductor alloy kit, containing over 25,000 semiconductor preforms including the latest alloys used in the industry, is now available from Accurate Specialties Co., Inc. Kit Z-100 contains a complete range of semiconductor preforms in usable forms such as discs, washers, and spheres, as well as new clad metals finding greater application in the industry, such as indium clad aluminum. Included are 24 different alloys for use in both germanium and silicon diodes, rectifiers, and transistors. Other alloys include tin-antimony, lead-silver, indium-germanium, tin-lead-antimony, 99.999% pure indium, aluminum-boron, etc.

Circle 106 on Reader Service Card

Gravity Convection Ovens



Especially qualified for accelerated Aging Tests in the Electronics Industry, Blue M Gravity Convection Ovens repeatedly inject fine degree of accuracy and uniformity into test results. Temperature Range: to 343°C. (650°F.) Reliable, straight-line control derived from Saturable Power Reactor Control System without contacts, switches, moving parts or auxiliary mechanisms to wear, burn or arc. Design of this unit permits installation of balances and mechanisms extending into work chambers, without vibration.

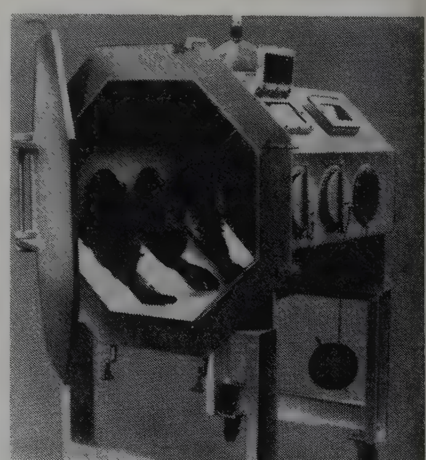
Circle 125 on Reader Service Card

Protective Cream

Sticky epoxy resins, often used with glass wool in laminating operations, are one of the largest sources of contact dermatitis in industry. A specially formulated protective barrier cream, "Kerodex" #71, when applied before operations, offers positive protection to workers' hands. The cream, available from Ayerst Labs, prevents sensitization of the skin by resins and amine hardeners, and offsets the irritant action of glass wool particles.

Circle 153 on Reader Service Card

Inert Gas Room



CAEMCO Inc., Vacuum Dry Box is a portable and complete Inert Gas Room which provides for working in a rare gas or for inert atmosphere welding. This Vacuum Dry Box can be evacuated to 50 microns with a leak rate of 1 micron per minute. Several people can work simultaneously. It is equipped with low-permeability Butyl gloves and evacuable glove ports, air-lock, fluorescent lamp, welding windows etc.

Circle 109 on Reader Service Card

(Continued on page 76)

THE TREND IS TO UNITRON

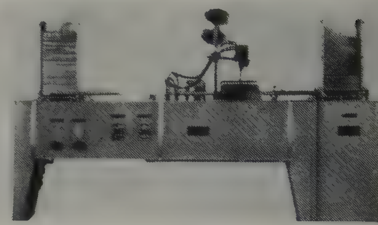
NEW SERVICE NOW AVAILABLE

SEMICONDUCTOR PRODUCTS is making a new source of information available to all firms interested in being kept up to date on materials or equipment for producing semiconductor devices. If you wish to receive all new literature on silicon, germanium, chemicals, machinery, or other such materials, circle #99 on the reader-service card. Your name will be placed on a special list which will be forwarded to all such suppliers. As these suppliers have news available in their field, you'll be notified by them immediately. This service is restricted to firms manufacturing semiconductor devices or firms contemplating entering into production within 120 days.

New Products

(from page 74)

Magazine Loader Accessory



A new accessory designed for the recently developed remote spray coater HD-3 and to facilitate the handling of axial lead components has been announced by Conforming Matrix Corporation. Model ML-1 magazine loader can also be used with Model HD-2 remote spray coaters now in use, after factory revision, which can be made in that model. The loader stacks in a portable magazine 40 loaded trays of axial lead components after they have passed through the painting station of the remote spray coater. The magazines may then be quickly transferred to baking or other processing operations.

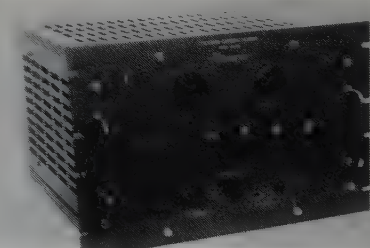
Circle 114 on Reader Service Card

Cleaning Equipment

Ultrasonics Corporation has introduced a new configuration of cleaning equipment for use in small parts production and in research laboratories. In the new units, high power is applied simultaneously to three or more containers. In a production process, each container can be filled with a different fluid so that small parts can be successively washed, rinsed, and final rinsed. In laboratory application, the unit may be used for simultaneously observing the effect of ultrasonic energy on different materials.

Circle 133 on Reader Service Card

Ultra Precision Current Source



A programmable constant current source has been introduced by North Hills Electronics, Inc., designed especially for gyros, semiconductors and magnetic components. Model CS-140 Current Governor furnishes currents from 0.1 μa to 150 ma for load voltages from 0 $\pm$ 100 volts. The current is set to 6 places by decade knobs arranged to provide 1 ppm resolution. Three full scales of 10 ma, 100 ma, and 150 ma are provided. Accuracy at any current setting is 0.01% F.S. Line and load regulation are better than 0.0025% for d-c outputs. The unit may be used as an *a*-*c* current source from *d*-*c* to 6 KC by driving it from an external modulating signal.

Circle 108 on Reader Service Card

(Continued on page 83)

Market News *(from page 70)*

Prices

Rheem Semiconductor Corp. has available a silicon diode 1N251 providing a 0.15 µsec reverse switching time. This hermetically sealed unit packaged in a subminiature case is priced at $3.50 each in quantities of 1-99. The firm also has an improved 1N1645B having eight times better reverse current leakage specifications than the 1N1645. The new unit is priced at $4.50 each in 1-99 quantities.

RCA, Somerville, N.J. has introduced seven new stud-mounted, ampere silicon rectifiers. Types 1N248-C to 1N250-C are priced from $3.50 each in quanities of 100-999. The 1N1195-A to 1N1198-A series are priced up to $18.75 each in like quantities. The firm also has made available four low-power silicon rectifiers housed in the TO-1 case. Types 1N3193 through 1N3196 are priced from ¢ to $1.10 each in lots of 1000 or more depending upon their voltage levels. Another device has been released which incorporates the planar design and combines two identical transistors. It will be priced at $25 each in lots of 1,000 units.

General Electric has announced price reductions ranging from 2% to 46% on all 22 models comprising two lines of its silicon low current potted rectifier circuit assemblies. The firm has also made available a new line of high current silicon controlled rectifiers. Prices are in the neighborhood of $67.50 per unit in large quantities.

Sperry Semiconductor has lowered its prices on silicon diodes and silicon transistors. Reductions up to 77% have been announced on nine items in their series 1N457 to 1N921 and up to 43% on 6 items in the series 2N327A to 2N1469. The firm has also increased the quantities of diodes that can be handled by its distributors from a maximum of 1,000 to 5,000 units.

Sylvania Electric Products, Inc. has disclosed price reductions of approximately 25% on their SYL2300 and SYL2301 epitaxial germanium mesa transistors.

Texas Instruments Ltd., British subsidiary of Texas Instruments Inc. is planning to market a new epitaxial silicon transistor for about $28 each.

Hoffman Electronics, Inc. has developed a silicon solar power unit consisting of 500 small cells for operating an AM radio and large loud speaker. The unit produces about 5 watts and sells for about $85.

Tyco Semiconductor Corp., Waltham, Mass., is offering an *n* type base gallium arsenide point contact varactor diode. Prices of these units range from $60 to $330.

Semiconductor Products division of Micro State Electronics Corp., Murray Hill, N.J. has announced prices on single and polycrystalline gallium arsenide. Single doped crystals with 3,500 cm²/volt-sec. minimum mobility are available from $23 to $17 per gram depending upon quantity. Crystals with a minimum mobility of 4,500 cm²/volt-sec. are priced from $30 to $24 depending on quantity. Large grain polycrystalline is also available at $8 to $7 in quantity.

Suppliers

The Electronic Chemicals Division of Merck & Co., Inc. has announced the availability of single and polycrystalline gallium arsenide in production quantities. The material is available in both doped and undoped form with carrier concentrations ranging from 1 x 10^{16} carriers per cubic centimeter to degenerate levels. Merck single crystal gallium arsenide has been produced in ingots as large as 90 grams and in diameters up to one inch.

Distributors

Atlas Electronics Inc., Perth Amboy, N.J. has been authorized as a distributor for General Electric semiconductors handling up to 1,000 pieces.

General Instrument Semiconductor Division has appointed four stocking distributors to provide immediate delivery of their complete line of transistors, diodes and rectifiers in the metropolitan New York-New Jersey-Long Island area. The four firms are: Arrow Electronics, Inc., Mineola, L.I., N.Y.; Milgray Electronics, Inc., New York City; Sun Radio and Electronics Co., Inc., New York City; Terminal-Hudson Electronics, Inc., New York City.

(Continued on next page)

Market News *(continued)*

Charleston Rubber Company of Charleston, South Carolina, announces appointment of Distributors Service Corporation, Los Angeles, as its service representative and warehousing distribution center for Charoc industrial products in 13 western states including Alaska and Hawaii.

The Birtcher Corporation's Industrial Division of Monterey Park, Calif., announced the appointment of Bell Electronic Corp. of Gardena, Calif. as distributor for its line of tube, transistor and component retention and cooling devices. Bell will act as distributor in the Southern California, Arizona and Southern Nevada territories.

Financial

General Instrument Corp. has reported a net of $1,123,023, equal to 47¢ a share for the three months period ending Nov. 30, 1960. This represents an increase of 21% over the $926,645 or 43¢ a share for the same period in 1959. Sales were $19,851,137 or 5.6% above that of one year earlier.

Cetron Electronic Corporation has acquired Scientific Optical Corp. of Azusa (Calif.) and its subsidiary, Precision Coating Laboratories, Inc., for an undisclosed amount of cash and Cetron stock.

Stockholders of CGS Laboratories, Inc., Wilton, Connecticut, has recently voted to change the name of the organization to Trak Electronics Company, Inc., in order to describe more appropriately the activities of the company.

International Resistance Co. has entered the rapidly-growing semiconductor field with the purchase of controlling interest in North American Electronics, Inc., of Lynn, Mass. NAE's major product lines include more than 600 types of silicon rectifiers and Zener diodes, as well as silicon-controlled rectifiers.

Westinghouse Electric Corporation has reported a net income for 1960 of $79,057,000 or $2.22 a common share, identical to the per share earnings from operations in 1959. A dividend of 30 cents a share on the common stock and 95 cents a share on the 3.80 percent preferred stock, was paid March 1 to stockholders of record February 6. Net sales billed in 1960 were $1,955,731,000, compared with $1,910,730,000 in 1959.

IBM's gross income in the U.S. for the year ended December 31, 1960, was $1,436,053,085, an increase of $126,265,048 over the previous year. Net earnings were $168,180,880, a $22,547,668 increase over 1959. Earnings per share were $9.18, based on the 18,310,954 shares outstanding at the end of the year. Earnings in 1959 were $7.97 per share on the 18,268,943 shares outstanding December 31, 1959. Progress in 1960 was highlighted by the rising flow of the company's new solid-state data processing machines.

Expansions

Trygon Electronics has enlarged their building in Roosevelt, New York, thus doubling their current production capacity, while also providing more room for their Research Division. The increased production capacity will afford extremely fast delivery of Trygon's wide line of transistorized power supplies. The new Research Division will develop new, high efficiency, energy conversion devices.

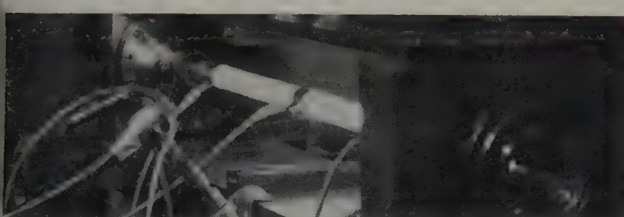
Wallson Associates, Inc., Elizabeth, New Jersey, manufacturer of a wide range of semiconductor test equipment, has established a high vacuum division. Engineering and production facilities of the new division will be housed in Wallson's Elizabeth plant.

Westinghouse Electric Corporation has announced the completion of a new facility at the semiconductor department at Youngwood, Pa. Devoted primarily to the development and processing of semiconductor materials, including new forms of silicon and germanium, the new 50,000-square-foot building is adjacent to the existing structure.

A new 10,000 square ft. plant facility has been opened by Semi-Alloys, Inc. in Mount Vernon, New York, for processing metals used in producing semiconductor products. The plant is housed in a modern, one story building and includes complete facilities required for producing high purity discs, wire, clad metals, washers, dots, spheres, rings, foil and special shapes. Production capacities are substantially increased and all services provided on the premises.

A 300-kw industrial rectifier which uses experimental high-current silicon-Trinistor controlled rectifiers has been built by Westinghouse Electric Corporation's rectifier and traction equipment department to determine the feasibility of using the devices for high-power industrial applications. This prototype model will supply 1200 amps continuously, 1500 amps for 2 hours or 2400 amps for 10 seconds. Output voltage is 250 volts. The circuit used in the rectifier is six-phase, double way. Westinghouse designer Willard Albert was responsible for the development of the new unit.

A breakthrough in research leading toward high frequency transmission appeared in an announcement by Bell Telephone Laboratories scientists of a continuously operating optical maser. The device uses a mixture of helium and neon gases for its active medium. It receives its energy from a low-powered (tens of watts) electrical discharge within the gas, and has an output power of about 1/100th watt. Lying in the infrared portion of the frequency spectrum, the beam of coherent radiation is highly directional, having a spread less than one minute of arc.



A gaseous optical maser on earth, operating through a suitable telescope, could send a beam to the moon that would cover a spot smaller than one mile in diameter. Optical gas masers and optical solid state masers are expected to complement each other in their applications.

A new lightweight nuclear generator which converts heat directly into electrical power is undergoing performance testing at the Air Research and Development Command's Air Force Special Weapons Center in Albuquerque, N.M. It was developed under Air Force contract to provide a reliable and long-life power source for facilities such as small unmanned surface radio beacons and weather stations. The completely portable nuclear auxiliary power device, which weighs less than 40 pounds, was designed and constructed by the new products laboratories of Westinghouse Electric Corporation in Pittsburgh. The generator produces approximately 150 watts of electrical power and was designed for one year of continuous unattended operation. It uses radioactive isotopes, such as Curium 242 as its heat source.

The generator's 144 small semiconductive elements are heated by this heat source to a temperature of about 1000° F. Finned heat exchangers, which cover the generator like the quills on a porcupine, keep the cold side of the elements at a temperature of 300° F. This temperature difference produces a flow of electrical current in the elements. The over-all device is only 10″ high and 16″ in diameter. It is another step in a series of developments by the Air Research and Development Command which will lead to increasing Air Force utilization of thermoelectric devices for converting nuclear energy directly into electrical power. The Air Force Special Weapons Center's Nuclear Power Applications Branch is conducting environmental, endurance, efficiency and maximum power testing under the direction of Captain Gerald McGovern of Washington, D.C. The thermoelectric couples used in the generator were fabricated at the Westinghouse semiconductor department plant at Youngwood, Pa.

Circle No. 35 on Reader Service Card

Circle No. 36 on Reader Service Card

NEW RESEARCH AID

SEMICONDUCTOR ALLOY KIT NO. Z-100

In order to satisfy the needs of semiconductor research and development engineers for development quantities of high purity alloy preforms, Accurate Specialties Co., Inc. has now made available this unique semiconductor alloy kit. Using this kit, research engineers can now speed the development of new devices and processes, without the delays and setup costs previously encountered in procuring small development lots.

Note . . .

Kit Z-100 consists of 24 different semiconductor alloys in various useable forms such as discs, washers, and spheres. In excess of 25,000 preforms, in alloys with melting points from 325 to 1100 deg. F., are contained in this kit.

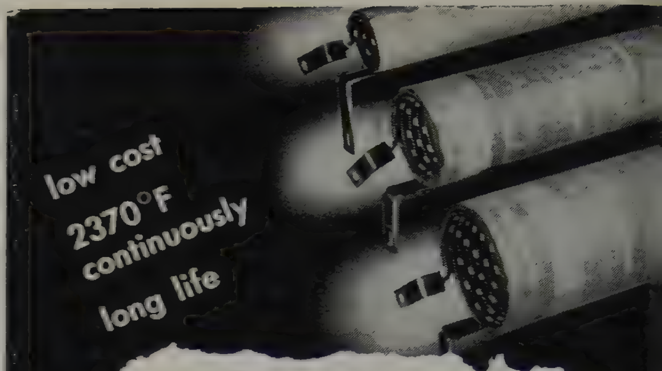
Accurate Specialties Co., Inc., metallurgical staff welcomes your inquiry regarding this kit, or your special semiconductor materials requirements.

price **$100.00** F.O.B. plant

Ask for Bulletin Z-100
Dept. SP-3

ACCURATE Specialties Co., Inc.
345 LODI STREET—HACKENSACK, NEW JERSEY—HUBBARD 9-4650

Circle No. 37 on Reader Service Card



KANTHAL® ceramic tube elements

World renowned Kanthal A-1 alloy (Fe, Cr, Co, Al) ceramic embedded in six, standard, ready-to-mount sizes for intermittent temperatures to 2460°F:

Type No.	Rating Max.	Volts Max.	Resistance	Inside Dia.	*Heating Length	List Price
REH-4-30	800 W.	15	0.26	1-9/16"	7-7/8"	$32.94
REH-4-60	1200 W.	29	0.65	1-9/16"	19-3/4"	$54.32
REH-7-30	1200 W.	24	0.44	2-3/4"	7-7/8"	$38.21
REH-7-60	1800 W.	46	1.05	2-3/4"	19-3/4"	$73.47
REH-10-30	1800 W.	34	0.59	4"	7-7/8"	$39.61
REH-10-60	2500 W.	63	1.44	4"	19-3/4"	$76.48

* Std. units can be arranged in series to provide a variety of heating lengths.

Ceramic mounting parts for above elements as well as complete laboratory furnaces also available. Write for brochures.

KANTHAL

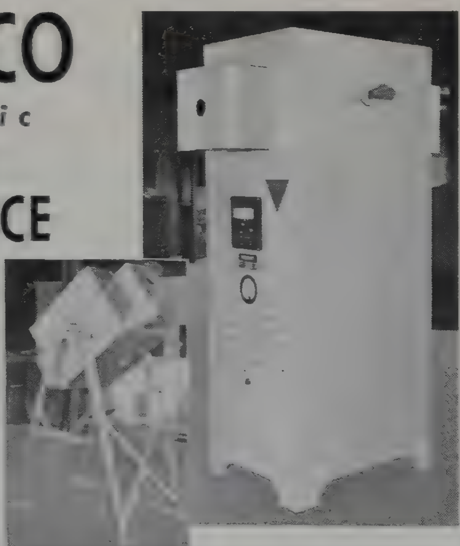
THE **KANTHAL** CORPORATION
19 Amelia Pl., Stamford, Conn.
Can. Rep., Ferro Enamels, Ont., Can.

Circle No. 38 on Reader Service Card

PERECO

Electric

TUBE FURNACE



Available in operating temperatures up to 2800° F.

- Horizontal or vertical models—in Cabinet or Trunion mounted.
- Selection of tube lengths and diameters.
- Either hollow silicon carbide (tubular) water cooled element, or ceramic tube surrounded by air-cooled silicon carbide elements.
- Designed for either normal or extremely rapid heat-up.
- Precision controls for wide range temperature control and turndown.
- Interlocked "Fail-Safe" protective devices combined with highest quality unit construction.

Pereco's years of experience and world-wide recognition as electric furnace specialists is assurance of their ability to help you with your requirements. Write

PERENY EQUIPMENT CO., INC.
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Columbus 12, Ohio

PERENY EQUIPMENT COLUMBUS OHIO

Circle No. 39 on Reader Service Card

SEMICONDUCTOR EXECUTIVES
$12,000 to $50,000

GENERAL MANAGER

[illegible] from reorganizing [illegible] division seeking [illegible] experience in the [illegible] field to take over [illegible] Must be both [illegible] administratively qualified [illegible] the facility and [illegible] executive and [illegible] Prefer heavy [illegible] and diode experience [illegible] to discussion plus [illegible] option and other [illegible]

DIRECTOR OF RESEARCH & DEVELOPMENT—$25,000

[illegible] manufacturer [illegible] Ph.D. with strong [illegible] background to [illegible] research & development [illegible] approximately 100 [illegible] well accepted in [illegible] with some managerial [illegible] Prefer man with business [illegible] Tower" approach. [illegible] opportunities.

SALES MANAGER—$16,000

[illegible] manufacturer of silicon [illegible] with 2 or more [illegible] selling semiconductor [illegible] sales department. [illegible] western third of [illegible] sales force [illegible] one year. Man [illegible] to hire and train new sales [illegible]

DEVICE DEVELOPMENT MANAGER—$25,000

[illegible] of silicon devices seeks [illegible] 5 years experience in device development [illegible] management [illegible] their Device Development [illegible] man with advanced degree.

PRODUCT MANAGER—$18,000

Medium sized [illegible] transistors and diodes seeks [illegible] to 5 years experience [illegible] of engineering [illegible] as product manager. Man [illegible] have knowledge [illegible] from R&D stage [illegible] and sales. Must be [illegible] military specifications [illegible] of keeping abreast [illegible] Should be business oriented.

PROJECT ENGINEERS—to $18,000

Have urgent requirements [illegible] neers with 3-5 years [illegible] any or all of the following fields: diffusion, photo-lithographic techniques, device design, surfaces, housing designs, and [illegible] processes on mesa transistors. Man will be rapidly promoted to Project Managers.

SCORES MORE

All expenses paid by employers. Completely confidential—no referrals without your permission.

If your are interested in knowing more about these and many other semiconductor executive positions available through our services but don't have a prepared resume simply jot your home address and phone number on the back of your business card and mail it to:

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SEMICONDUCTOR DIVISION

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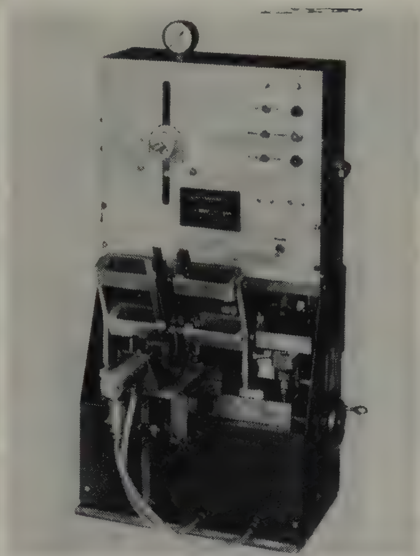
SERVING THE ELECTRONICS INDUSTRY EXCLUSIVELY —WITH INTEGRITY

New Products

(from page 76)

Automatic Lead Straightener



A new automatic component preparation machine which straightens both leads and aligns them perfectly with the body of components, such as capacitors, resistors, diodes, etc., has been developed by the Design Tool Company, Division of Federal Manufacturing & Engineering Corp. The Auto-Straightener, Model AUS, handles all size bodies and straightens the component leads at 3,000 or more parts per hour depending upon the method of feeding. Component manufacturers and large volume component users can eliminate axial leads displaced as much as ⅞". Also handles short run production.

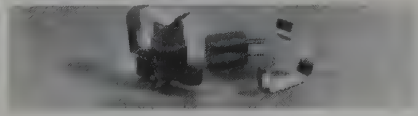
Circle 107 on Reader Service Card

Zener Diodes

Dickson Electronics Corporation introduces four new Zener Diode product lines. The diffused junction devices are rated at ¾, 1, 1.5 and 10 Watts and cover the voltage range of 6.8 to 200 volts. All units contain single *p-n* junctions formed by carefully controlled diffusion at 1300° C of phosphorus into boron doped silicon. All units are curve-traced to eliminate unstable breakdown or other anomalous effects and are checked 100% to electrical parameter limits.

Circle 111 on Reader Service Card

Transistor Spring Clips



Birtcher Corporation/Industrial Division has introduced two new retaining clips for socket mounted TO-5 and TO-9 series transistors to comply with military requirements for retention of plug-in devices. The Spring Clips, 3B-714-1 and 3B-714-2, provide a positive spring pressure retention on the transistor case top and easy access for service. Two heights are available; for transistors with mounting height dimensions of 13/64" and 21/64".

Circle 124 on Reader Service Card

Thickness Selector

The Ballthrall Engineering Compan announces the availability of an Auto matic Thickness Selector for Germaniu pellets. This Selector, using an air mi crometer, is capable of measuring 120 pellets (round, square, or rectangula an hour, to an accuracy of ±1 micro and then sorting them into 12 receivin boxes in accordance with their thickne

Circle 145 on Reader Service Card

Ultrasonic Cleaner

The diSONtegrator System Eighty, 1½ gallon capacity ultarsonic cleaner, ha been introduced by Ultrasonic Industrie Inc. The System Eighty, guaranteed fo five years, features a broad band fre quency modulated circuit which elimi nates the need for automatic tuning a found in much higher priced equipmen The generator is rated at 120 watts aver age power—480 watts peak power outpu Fused for 5 amps, the generator operate from 117 volt-50/60 cycle line current. A 220 volt-50/60 cycle export model is avail able at slight additional cost.

Circle 117 on Reader Service Card

Heat Treating Furnace

Design for heavy and continuous duty at all levels up to 2500°F, with somewhat higher temperatures available for short or intermittent runs, is a prime characteristic of SM-AD Series general-purpose heat treating furnaces announced by The Pereny Equipment Co Rapid "heat-up" and "recovery," extreme flexibility in heating cycles, and availability in a range of sizes with a choice of controls, also make this unit equally suited for shop, tool room or laboratory use. Current requirement is 12.5 KW.

Circle 130 on Reader Service Card

Silver Conductive Adhesives

Isochem Resins has announced a series of conductive adhesives based on a new type of conductive silver that is a true conductor over a wide temperature range. The Isochemduct 2.5 is a two part system for top conductivity while the Isochemduct No Mix gives us No Pot life plus no mixing losses on this expensive type adhesive. Available in a variety of viscosities and forms and can be modified to customer requirements.

Circle 127 on Reader Service Card

Precision Voltage Source

Electronic Development Corporation has introduced a new Precision Voltage Reference Source which features an increased voltage range of −111.11 volts *d-c* to +111.11 volts *d-c*, selectable in 10 millivolt increments. Model VS-111 is a 4-decade direct-reading all solid-state instrument available in portable or standard rack-mounting models. Absolute accuracy is 0.025% and resolution is 1 part in 10,000 plus vernier resolution.

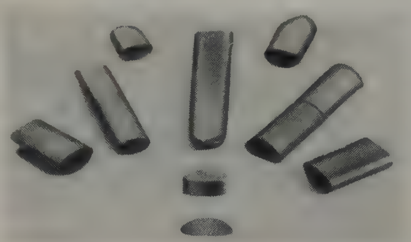
Circle 113 on Reader Service Card

Large Size Readout Lamps

Rayescent readout lamps are now available from Westinghouse in a new large size. They have been designed to display letters and numbers by electroluminescence in many military and industrial applications. They operate at either 240 or 460 volts, and at 60 or 400 cycles per second. The lamp uses only 0.01 watt when all segments are lighted. Small, compact, transistor-type power packs can be supplied for converting 60 cps or low-voltage *d-c* power into 400 cycles when higher brightness is necessary.

Circle 144 on Reader Service Card

High Purity Material



The Semiconductor Products Division of Micro State Electronics Corporation is now producing commercial quantities of single and polycrystalline Gallium Arsenide. Recent developments in the technology of GaAs crystal growth have made it possible to offer *N*-type single crystal material with mobilities ranging from a minimum of 3500 cm^2/volt sec. to over 5500 cm^2/volt sec. This material's superior quality is demonstrated by a large increase in mobility at low temperature and by uncompensated carrier concentrations in the order of 10^{16} per cm^3. In addition, doped single crystals with impurity densities suitable for varactor and tunnel diodes are available.

Circle 142 on Reader Service Card

Diode Evaluator

A Diode Evaluator has been developed by Dynatron Laboratories to test *d-c* parameters of semiconductor diodes. The company states that the instrument is designed to provide a fast and accurate method to check and select up to 10 matched diodes at one time. An amplifier extends the capability of measuring leakage current to 0.1 microamperes. A remote connection is supplied to render the Evaluator useful for monitoring diodes undergoing environmental tests, or for testing diodes not accommodated by quick snap connectors.

Circle 119 on Reader Service Card

Secret Communication System

A new communication system that uses "ray guns" to transmit voices secretly and silently by means of invisible beams has been announced by the Aeronautical Division of Minneapolis-Honeywell. The system makes use of sending and receiving units shaped like guns. They are aimed at each other for the transmission of a narrow beam of infrared radiation. Words spoken into the gun are electronically converted into infrared beams and transmitted to the receiver which converts the message back into sound. The optical assembly consists of a lamp housing, condensing lens system, germanium semiconductor modulator crystal, lead sulfide detector and collecting optics.

Circle 131 on Reader Service Card

High Power Silicon Rectifier

Greater electrical power to help t Army's tanks of the future seek out t enemy and aim their guns electronica is provided by a new electrical pow supply device announced by ITT. T device is a new type of high power si con rectifier unit. It combines smalln of size, resistance to shock and vibrati and high electrical power output at te peratures up to 250°F. Voltage rat 30 volts *d-c;* current rating, 400 ampe *d-c;* cooling oil temperature, 248° F; co ing oil flow rate, 3 gallons per minu minimum.

Circle 137 on Reader Service Card

Piston Capacitor

The components division of JFD Ele tronics Corporation has developed variable slope piston capacitor, t VCJ258A. The sliding piston unit is i tended for applications where the tuni adjustment is accomplished by mea of a cam. The variable slope is obtain by controlling the amount of overlap the fixed and movable plates of t capacitor. Among the many features the unit are: Low temperature coefficie of capacitance ±100 ppm/°C, wide ope ating temperature range of −55 to +12 C.

Circle 154 on Reader Service Card

High Temperature Furnace

Jelrus Technical Products introduces th "Electro-Melt," a new high temperatu (2300°F) crucible furnace for melti metals, heat treating, sintering, ceram firing and general research. Muffle dime sions 4" I.D. x 7½" high. Metal melti capacity 5# bronze. Equipped with aut matic temperature controller and therm couple failure protection. Available 1 to 230V *a-c.* Heating element is hea Kanthal wire (⅛" x 7/32") operating low voltage (40 Volts).

Circle 158 on Reader Service Card

Heat Dissipaters

Vemaline Coolers are now wide used in electronic circuitry, on pow supplies, computers, aircraft and missi electronics equipment. The 6071 natur convection cooler is suitable for mo applications; mixed hole patterns a available; more than one semiconduct can be mounted on same cooler. Ho patterns are available for all standa transistors, diodes and rectifier configur tions. The fins are surrated for maximu surface area in order to obtain utmo performance. The coolers are coined minimize contact resistance (0.5°C Watt). Special coolers are available longer than 3-1/16" length on reque The Heat Sink compresses 150 squa inches of radiating surface.

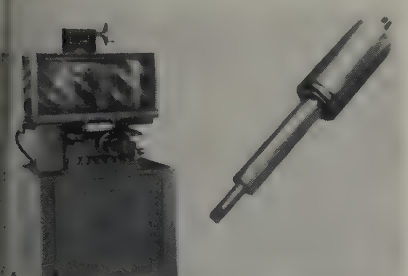
Circle 151 on Reader Service Card

Hayes Equipment

new "transistorized," constant-phase [illegible]rol unit providing exact, microsecond [illegible]lation of power output and operat[illegible] temperatures of electric furnaces, and [illegible]w, high-frequency induction heating [illegible] with heating stations and power sup[illegible] generator in a single, compact con[illegible] have been introduced by C. I. Hayes, [illegible] The pHayes-master (TM) Power [illegible]plifier Control Unit uses silicon con[illegible] rectifiers and other semiconductor [illegible]ices. Space saving is up to 75%. [illegible]ndard capacities are 10, 15 and 70 [illegible]s, 115 or 230 volts, single and three[illegible]se. High-frequency induction heating [illegible]ipment features compact unit con[illegible]iction and fully-automatic controls. [illegible]h radio frequency and motor genera[illegible] units are available in 3, 5, 10, 20, 30 [illegible] 60w capacities, with 3-phase, 60-cycle [illegible]ver supply, and with single or mul[illegible]e (up to 5) heating stations.

Circle 157 on Reader Service Card

[illegible]tridge Spindle



A new cartridge spindle designed to [illegible]rmit the use of thinner, smaller-diam[illegible]er diamond wheels to reduce kerf [illegible]sses in the slicing of germanium and [illegible]icon is announced as standard equip[illegible]ent on all Micromech mechanical and [illegible]draulic automatic wafering machines. [illegible]is cartridge spindle, Type 2, provides [illegible]p wafering efficiency with wheels of [illegible]l sizes as well.

Circle 100 on Reader Service Card

[illegible]miconductor Reliability Test System

Developed to meet the needs of newly [illegible]stablished reliability programs, Opti[illegible]ized Devices' Semiconductor Reliability [illegible]est System will provide repetitive [illegible]st data from lots of transistors and/or [illegible]iodes. Purpose of the system is to auto[illegible]atically program, test, evaluate and re[illegible]ord continuous test data on an IBM [illegible]utput Writer or Card Punch. Semicon[illegible]uctors may be tested in ambient or con[illegible]olled environments. Silicon or germa[illegible]ium transistors or diodes may be tested [illegible] lots of fifty or more. Test accuracy [illegible] ± 1%. Repeatability is ± .2%. Human [illegible]ecision and recording is completely [illegible]liminated. Power capability is 0-3 am[illegible]eres; 0-1000 volts.

Circle 102 on Reader Service Card

[illegible]esin Dispensing Machine

Metering, mixing and dispensing small [illegible]uantities of two-component resin sys[illegible]ems over a wide range of materials and [illegible]perating conditions is possible with [illegible]e new "Micro-Shot" machine, an[illegible]ounces Automatic Process Control, Inc. [illegible]esigned to produce a shot volume from [illegible] fraction of a cubic centimeter to 20 [illegible]ubic centimeters, the machine is par[illegible]cularly applicable for adhesive and [illegible]asting jobs. Suitable for end capping [illegible]icromodules, transistors, resistors, ca[illegible]acitors, etc.

Circle 140 on Reader Service Card

Sampling Oscilloscopes

Nanosecond dual trace displays a now possible with the new Lumatr Model 112-9 Dual Channel Sampling O cilloscope which features a risetime 0.4 nanoseconds, calibrated sensitiviti to 2.5mv/centimeter and a noise level less than 0.6mv. Particularly importa in waveform analysis is the instrumen ability to display two separate wav forms, or a single waveform, at tw different sweep speeds. The instrument particularly useful in the measureme of the switching characteristics of ult fast circuits, transistors, diodes, and oth solid state devices.

Circle 136 on Reader Service Card

APPLICATIONS

(*from page 57*)

the circuit gain requires the use of a additional stage of amplification be tween Q_2 and Q_3 (see *Fig. 60.3*). Fo 0 to 15 ampere operation, the combine gains of Q_2 and Q_3 must be 140 o greater to achieve 1% regulation. T achieve the same regulation over th current range without adding addition gain, R_5 must be increased to abou 0.06 ohms. This appears to be the bette method of maintaining regulation whe paralleling tetrodes because, with th former method, the additional gain o an added stage may cause system in stability (oscillation).

PERFORMANCE

The performance of the voltage reg ulator is affected by the temperature a which it must operate. As the tempera ture increases, the minimum-controlla ble load current increases and th maximum-allowable load current de creases. The minimum load current a which regulation is maintained at particular temperature is the syster leakage current at that temperature. load current less than this leakage cur rent cuts off Q_1 and the output voltag rises to the input voltage. The maxi mum-allowable load current depend on the power the tetrode is able to dis sipate for a particular tetrode mount ing base temperature.

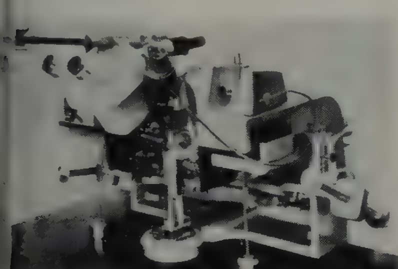
The high-temperature performanc of the circuit can be improved b using a Honeywell 2N1659 transistor fo Q_2. Its lower leakage current permit operation at higher temperature befor loss of no-load regulation and loss o short-circuit protection occurs. Th regulation is poorer, however, due t its lower gain.

Another method to maintain no-loa regulation at high temperatures is t place a bleeder resistor across the out put terminals. Its value should be suc as to cause the system leakage curren at the expected temperature, to flo with the output voltage at the desire level. This method is effective but increases the standby power and fur ther raises the temperature of the cir cuit.

Semiconductor Technology

new production instrument, designed it a target too small to be seen by naked eye with a wire one-sixth the neter of a human hair, gives the conductor industry speed and econ- in operations that demand high pre- on in feeding and bonding fine wire. riginally created for use in the manu- ure of mesa-type transistors, the ipment also can be used in the pro- tion of mesa and varactor diodes, r cells, planar structure transistors, axial mesas, micro-modules, molecu- electronic devices and integrated cir- s.

esigned and built by Kulicke and a Manufacturing Company, Inc., the machine is known as the K & S rmocompression Wire Bonder, Model A binocular microscope enables the rator to see the target, a stripe that asures one thousandth of an inch 001") wide by three thousandths of an h (0.003") long, to which fine gold e is bonded.



A system of controls, designed and tented by the company, translates the erator's gross finger movements into inute manipulations in both the hori- ntal (x-y) and vertical (z) planes to sition the wire and the bonding tool. sitioning precision of ten to fifteen illionths of an inch (0.000010" to 00015") can be achieved.

Other production machines designed nd built for the semiconductor industry y K&S include scribers and multi- ribers, wafer bonders, nail-head bond- s, production probes and micro-posi- oners.

Circle 155 on Reader Service Card

Device Applications

Trepac Corporation of America, Englewood, N.J., announces a new High Speed Transistorized Telegraph Relay, designed to electrically and mechanically replace Polar Relays used in Teletype machines and Central Office Telegraph repeaters.

Computer Logic Corp., Los Angeles, announces the DN-1 transistorized plug-in module. Based on diode-NOR logic, each card contains four transistorized circuits which can be connected as flip-flops, one-shots, & logic gates.

A new photoelectric tape reader, incorporating chopped reflected light, has been developed by Omnitronics, Inc., Philadelphia 23, Pa., a Borg-Warner Subsidiary. Model PTR-7 also features such components as silicon solar cells, solid-state amplifiers and power supply and simple mechanisms.

A solid state transistorized direct current generator regulator for aircraft use was described by B. M. Van Emden, of Automatic Development Corp., Culver City, Calif., at the Winter General Meeting of the American Institute of Electrical Engineers.

A new miniaturized Static Position Light Flasher is announced by Joseph Pollak Corporation, Boston, Mass. This Flasher is fully transistorized and potted.

The Power-Prop, a new solid state stepless control for furnaces, is manufactured by the Stepless Controls Corporation of Waltham, Mass. This new device applies solid state switching to produce full range proportional control by use of silicon controlled rectifiers.

A series of three miniature, transistorized amplifiers, developed by Thompson Ramo Wooldridge Inc., Cleveland, were used in the medical electronics instrumentation system of the Project Mercury capsule during its recent successful launching.

Litton Systems, Inc., Model AD11-08S shaft angle encoder is less than 1.4 inch in length and weighs only 1.8 ounce, including silicon isolation diodes and 15 inches of wire leads. Silicon switching diodes are internally wired in series.

A complete hearing aid no bigger than a thumbnail has been developed by the Otarion Listener Corporation, of Ossining, N.Y. The miniature ear aid contains within its small circumference a microphone, battery, receiver, complete volume regulator and subminiature components including transistors.

A microminiature transmitter, so compact that the entire unit including its battery is mounted as a tooth in a dental bridge, was shown at the American Astronautical Society Seventh Annual Meeting. The tiny aid to aerospace medical research was developed by Varo, Inc. of Garland, Texas and is being used by the U.S.A.F. Aerospace Medical Center at Brooks AFB. The electronic device was constructed by using Microcircuitry techniques.

Christie Electric Corp., Los Angeles, announces Stepless Automatic Battery Chargers. Hermetically sealed silicon rectifier elements offer maximum efficiency.

New Literature

wo-color, four page folder designed buyers and engineers in the selec- of Westinghouse Silicon Power Rec- s, Silicon Power Transistors and moelectric Coolers has been pre- by Schweber Electronics. The r, which is fully illustrated, gives lete details of ratings, etc., in quick- ence, tabular form.

Circle 160 on Reader Service Card

four-page, 8½-by-11 inch, two-color og folder, illustrated with photo- hs and detail drawings, is available the new K&S Thermocompression Bender, Model 402, from Kulicke Soffa Mfg. Company.

Circle 161 on Reader Service Card

15-page short-form presentation de- pes all currently manufactured Tek- ix Oscilloscopes and associated elec- ic equipment. The catalog includes conventional oscilloscopes, 6 portable lloscopes, and 12 rack-mount versions addition to the following associated rumentation: 16 "letter-series" and 8 mber-series" Tektronix Plug-in Units, se-Sampling System, Rotan System, Current Probe System, various e-Mark, Square-Wave, and Pulse nerators, plus the G-12 Oscilloscope nera, and other electronic equipment.

Circle 162 on Reader Service Card

new catalog featuring the line of omatic component handling equip- nt designed for use by component nufacturers and volume users of ca- itors, transistors, coils and other com- nents, has been issued by Design Tool mpany, Div. of Federal Manufacturing Engineering Corp. This short-form alog contains full data on axial lead aightening machines, lead trimming d bending machines, circuit board in- ting and assembly machines, as well as variety of automatic devices designed to erate at high speeds with card loaded bulk loaded components.

Circle 163 on Reader Service Card

Two convenient, time-saving wall arts have been prepared by General ectric to assist in the selection of timum silicon and germanium rectifier mponents for basic circuits. The recti- r Selection Chart (ECG545) and Char- teristics of Common Rectifier Circuits art (ECG546) may be used independ- tly or to complement one another.

Circle 164 on Reader Service Card

A detailed study of precious metal ectrical contacts, their applications and ection criteria is included in a recent ue of Engelhard Industries Technical lletin (Vol. 1, No. 2) together with her articles in thermocouple materials, oblems posed by radioactivity in the ining of precious metal scrap, a review a technical film on refining precious tals, and abstracts of recently issued S. patents concerning precious metals.

Circle 165 on Reader Service Card

(Continued on next page)

New Literature

(continued)

Philco Corporation's Lansdale Divis has published a "Transistor Guide Switching Circuit Designers." The gu has been devised to aid engineers in lecting the proper transistors for s applications as saturated DCTL, SC RTL, RCTL, and DTL low-level l circuits. Also discussed are nonsatura logic such as current switching, medi level switching up to 400 ma, and h level switching including *d-c* to *d-c* c verters and static relays.

Circle 166 on Reader Service Card

Bellows-sealed, air-operated solen controlled valves for use in high vacu applications, are described in a spec cation sheet offered by Vacuum-El tronics Corp. Designated Veeco Ty "PV," the valves are engineered to p form 100,000 cycles without maintenan The sheet contains full technical spec cations. It also describes pneumatic co version kit, Type PVK, for changi manual Veeco bellows-sealed valves pneumatic operation.

Circle 167 on Reader Service Card

New 4-page, 2-color Bulletin describ Monitor Systems, Inc., Semi-automa Component Tester (SACT) for ultr reliable testing and classification of tra sistors according to user specifications speeds of 30 to 60 tests per second a resolution below a fraction of a micr ampere. Typical test specifications, flo diagram, and test circuits are shown.

Circle 168 on Reader Service Card

E. W. Pike & Co., Inc., manufacturers illuminated magnifiers and microscop describes full line in new illustrated br chure. Special models and accessories a also presented in this complete yet co cise piece of literature.

Circle 169 on Reader Service Card

A line of stud-mounted semiconduct bases and mating caps is reviewed in four-page technical bulletin from Stan ard Pressed Steel Co. The bases doub as heat sink and electrically-conducti mount for transistors, diodes and oth types of semiconductors. The vario critical dimensional tolerances, as clo as .001 inch on flatness of certain surface are detailed in the literature.

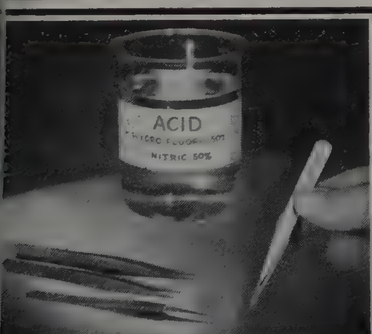
Circle 170 on Reader Service Card

A condensed catalog of high vacuu components and equipment manufacture by NRC Equipment Corporation is avai able. The 8-page catalog summarizes th complete line of high vacuum mechanic and diffusion pumps, valves, gauges, ac cessories, portable pumping system coaters, furnaces, electron beam welder altitude chambers and freeze dryin equipment.

Circle 177 on Reader Service Card

Information on a special black glass fo encapsulating diodes is given in a ne eight-page brochure published by Corn ing Glass Works. The illustrated bookl says the black glass, which is availab as beads and as cases, protects diodes th are sensitive to visible and infrared wave lengths. Transmittance and other prop erties are detailed in a chart and a tabl Information includes sizes, sealing tech niques and recommended applications.

Circle 178 on Reader Service Card



Personnel Notes

Martin B. Judge has been appointed director of the Electronic Chemicals Division of Merck & Co., Inc. He replaces Dr. George Krsek and reports to Dr. William H. McLean, president of the Chemical Division. Mr. Judge previously was manager of the Electronic Chemical Division's Technical Department, with responsibility for silicon process and product development as well as production and engineering.

F. W. Gutzwiller has been appointed manager of application engineering for the General Electric Rectifier Components Department. He will be in charge of developing new and broader uses for semiconductor rectifier components as well as assisting customers in solving specific application problems.

The appointment of Lester P. Creaser as semiconductor sales engineer at the Lansdale Division of Philco Corporation was announced recently. He will represent the division's transistor and tunnel diode product lines in the New England area.

JFD Electronics Corporation, Brooklyn, N.Y., announced the following appointments: William Bellenkes, Western Regional Sales Manager; George Kase, Eastern Regional Sales Manager; Fred L. Strauss, metropolitan New York area; "Sarge" Barkett, District Sales Engineer for the north central states; John Neenan, District Sales Engineer for the New England area; David Taub, Distributor Sales Supervisor.

Daniel Gray, research chemist noted for his work on Indium, has been appointed special consultant on technical problems by Alpha Metals, Inc., Jersey City, N.J. Mr. Gray was a leading research chemist with Oneida, Ltd. for 42 years.

The promotion of Bert King to the post of assistant sales manager was announced by Herbert S. Davidson, president, Milgray Electronics, Inc., 136 Liberty Street, New York City. Mr. King joined the wholesale industrial distributing firm four years ago as a field salesman. His prior background covered a period of ten years as purchasing agent in electronics firms.

Dr. Charles Eisler, Chairman of the Board of Eisler Engineering Co., Inc., Newark, N.J., is the founder of the successfully operated company which has borne his name for the past 40 years. His natural inventive genius as a boy and his eventual conquering of numerous hurdles to achieve a long list of inventions, with more than 50 patents registered to him, are covered in a highly readable human document, "The Million Dollar Bend." The recently published biography discusses fully Dr. Eisler's many inventions and covers the progress of various aspects of the electronics industry.

Dr. Richard B. Adler, Professor of Electrical Engineering at Massachusetts Institute of Technology, has been named to the Board of Directors of Solid State Materials Corporation of East Natick, Mass.

INDEX TO ADVERTISERS

For reference purposes, the advertis[...] index includes all regular adverti[...] who have run within the current co[...] tract year. These advertisers who app[...] in this issue are indicated by the pa[...] number adjacent to their listing, and a[...] shown in a bold-face type.

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2N504	High Gain IF Amplifier
2N588	Oscillator, Amplifier, to 50 mc

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